JOURNAL

OF THE

AMERICAN WATER WORKS ASSOCIATION

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VOL. 15 JANUARY, 1926 No. 1

EFFECT OF WATER RATES AND GROWTH IN POPULATION UPON PER CAPITA CONSUMPTION[1]

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Periodically every administrator of an important water works property is confronted with the necessity for reviewing critically the relative capacity and probable future demand for water upon his works. With growths in population of 20 to 30 per cent per decade, normal in this country, experience has shown that radical extensions and betterments are required at periods of twelve to fifteen years. The periods of economic design for different portions of the plant vary, of course, as for instance with the major sources of supply it is generally found advantageous to look forward and build structures for periods in advance of forty to fifty years. With a distribution pipe system which can be reinforced from time to time, a period of anticipation of fifteen to twenty years is more common.

In the case of the sources of supply, particularly in the semi-arid and arid regions and the rapidly growing regions of the East, it becomes of importance to anticipate the needs and purchase the necessary water rights lest their purchase at a later date, with the cost involved in the developments that may have been made or structures that may have been built upon them, be prohibitive.

[1] Presented before the Pennsylvania Water Works Association, October 22, 1925. Reprinted here by permission of the Pennsylvania Water Works Association.

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The scope of this paper is limited to certain factors involved in the determination of the future water demand.

It is customary first to make a careful study of the probable future growth in population of the region, which may be accomplished in various ways. In most of our large cities a valuable check upon estimates may be had through the work of the American Telephone and Telegraph Company which makes very careful studies along this line, which will be found helpful in checking independent studies made from the water works point of view.

Next most important is the problem as to what is likely to be the change in rate of water consumption per capita. In this are involved various considerations,—first and most important, the character of the industrial demand; second, the less important commercial demand and the demand of the public service; and finally the demand of domestic service. Unfortunately records of the total amount of water consumed by large industries and the earnings derived therefrom from year to year have not been determined even upon the works more or less fully metered, upon which the data could be assembled. This is much to be regretted. A change in practice is highly desirable. It would almost certainly lead to better administration to have such summations made annually, and with the statistical machinery now available such work can be done at costs well within reasonable limits. If it be not possible to gather such data annually, they should be assembled at least at periods of five years, that they may be coördinated with other factors such as the activity of industry and business.

In default of exact information in regard to total industrial consumption it has been necessary to base the present studies upon the more general information concerning total metered consumption, population and rates.

In looking forward to the future in comparison with the past it is necessary to make estimate of the effect of the increase in population upon daily per capita water demand, and the effect of changes in water rates. There are few, if any, works in which the water rates have remained constant over a long period of years, and the recent war has, of course, materially changed these conditions, resulting in general increases from 35 to 50 per cent in excess of prewar prices, and the tendency in rates is still upwards.

Another means of ascertaining future water demand is found in a forecast of past water consumption, but this too is inadequate and in most cases a more or less uncertain procedure because of the lack of exact knowledge concerning the slip of pumps and the amount of waste and leakage. Moreover in applying this yardstick also, the effect of increase in population and changes in rates must be borne in mind.

The local data if reasonably complete, when finally assembled and fairly treated, should furnish much the best criterion and be of greatest significance in the determination of probable future demand. Nevertheless, it is helpful often to see what the general trend of experience has been, as well as the experience of individual works in communities the character and life history of which are more or less definitely known.

It was with a view to determining such trends that the present work was undertaken. The effort has been made, through assembling the records of 29 different works which have been metered for comparatively long periods of years and are now substantially fully metered, to see if the record might not contain evidence of value. The records assembled have been those most available and covering a wide range of populations and water rates.

In table 1 are shown "Data on consumption, per cent of services metered and water rates for several cities." To this record of 29 cities has been added the record of New York City merely for purposes of comparison, because it was the largest city in the country and might be of interest in the plotting of the results, but inasmuch as but 25 per cent of the water services of the city are metered the record has not been given weight in the analysis of results, which are based essentially upon the records of the 29 cities cited.

These records were obtained by correspondence with the superintendents of the various works and after assembling the table, copy was resubmitted for comment and correction. It is difficult, of course, to make such a compilation which shall be absolutely comparable in every way, but the effort has been made here to get a record which should be as fairly characteristic and significant as possible.

The diagrams have been based upon the population figures shown in table 1, the probable present safe amount of the per capita water consumption in gallons per day; and the statement of rates in the three groups—domestic, intermediate and manufacturing, following

TABLE 1

Data on consumption, per cent of services metered and water rates for various cities

CITY	POPULATION SERVED 1920	AVERAGE DAILY CONSUMPTION (M.G.D.) 1924	PER CENT OF SERVICES METERED		PER CAPITA WATER CONSUMPTION IN GALLONS PER DAY							AVERAGE WATER RATE[1] PER 1000 GALLONS		
												Gallons per month		
			Average 5 years 1920–1924	1924	1920	1921	1922	1923	1924	Average 5 years 1920–1924	Probable present safe amount	25,000 (Domestic)	250,000 (Intermediate)	2,500,000 (Manufacturing)
New York City, N. Y.	5,663,980[2,4]	789.2[2]	26	25	130.0[2]	127.0[2]	128.0[2]	131.0[2]	131.0[2]	129.0[2]	135[2]	$0.13	$0.13	$0.13
Massachusetts Metropolitan District	1,213,430[4]	124.10	82	95	105.0	95.0	94.0	97.0	95.0	97.0	100	0.21[9]	0.19[9]	0.18[9]
Detroit, Mich.	1,061,972	183.97	98	99	143.0	143.0	148.0	135.0	134.0	141.0	140	0.10[10]	0.08[10]	0.06[10]
Cleveland, Ohio	925,283	151.18	98	98	151.7	135.0	137.3	149.6	140.8	142.9	145	0.08	0.08	0.08
Boston, Mass.	751,810[4]	87.68	73	94	125.0	112.0	110.0	113.0	111.0	114.0	115	0.21	0.19	0.18
Milwaukee, Wis	500,000	69.02	98	99	133.8	122.2	124.5	132.0	125.4	127.6	130	0.10[10]	0.09[10]	0.09[10]
Cincinnati, Ohio	414,500	48.94	100	100	119.4	114.7	117.0	115.6	115.1	116.4	120	0.16	0.16	0.16
Newark, N. J.	414,216	43.6	94	96	108.2	91.8	95.4	99.8	97.8	98.6	100	0.15[10,11]	0.14[10,11]	0.13[10,11]
Minneapolis, Minn	380,582	42.77	100	100	98.8	100.0	100.0	107.0	102.5	101.7	105	0.08	0.08	0.08
Kansas City, Mo.	334,193	48.33	81	83	142.6	132.3	138.3	132.5	125.9	134.3	135	0.22	0.17	0.11
Rochester, N. Y	278,000	26.4	99	99	95.7	96.2	88.8	86.3	85.6	90.5	90	0.18	0.17	0.15
Providence, R. I.	270,472	23.62	94	95	80.0	78.5	81.2	86.0	83.0	82.0	85	0.24	0.17	0.11
Toledo, Ohio	243,164	29.0	99	100	104.0	101.0	109.0	106.0	102.0	104.0	110	0.13	0.12	0.11
Columbus, Ohio	240,000	23.20	99	99	94.1	82.3	83.6	88.5	85.9	86.9	90	0.16	0.16	0.15
St. Paul, Minn.	234,698	20.38	96	98	81.2	80.7	81.6	80.1	72.7	79.3	80	0.09[10]	0.09[10]	0.09[10]
Worcester, Mass	179,923	16.27	97	98	92.1	82.5	84.5	85.1	84.5	85.7	90	0.20	0.15	0.10
Hartford, Conn	165,000	16.16	100	100	78.6	76.7	84.1	95.6	88.8	84.8	90	0.16	0.16	0.10
Grand Rapids, Mich.	145,000	15.91	99	99	98.0	94.0	98.0	113.0	99.0	100.0	105	0.09	0.09	0.09
New Bedford, Mass.	131,350	9.71	95	93	78.0	71.0	71.0	77.0	67.0	73.0	75	0.16[10,12]	0.10[10,13]	0.10[10,13]
Springfield, Mass.	130,114[5]	13.52[5]	99	99	96.0[5]	90.0[5]	87.0[5]	91.0[5]	89.0[5]	91.0[5]	95[5]	0.18	0.08	0.07

Fall River, Mass	124,843	6.79	100	100	51.1	55.3	49.5	54.1	51.9	52.4	55	0.28	0.20	0.14
Lowell, Mass	112,759	6.54	89	90	63.4	58.0	56.1	54.5	52.3	56.9	60	0.28	0.28	0.28
Yonkers, N. Y	101,176	13.41[6]	100	100	110.0[6]	105.0[6]	114.0[6]	112.0[6]	122.0[6]	113.0[6]	120[6]	0.21[12]	0.13[12]	0.13[12]
Lawrence, Mass	94,270	4.64	96	97	49.0	43.0	46.0	46.0	45.0	46.0	50	0.20	0.20	0.20
Brockton, Mass	80,206	4.19	100	100	43.3	43.6	43.9	47.3	50.0	45.6	50	0.26[10]	0.16[10]	0.14[10]
Manchester, N. H	80,000	6.35	83	85	67.7	66.5	68.4	76.2	76.6	71.1	75	0.13	0.13	0.10
Woonsocket, R. I	48,360	3.07[7]	96[8]	96[7]	53.0	50.7	53.8	59.8		54.3[8]	60	0.28	0.14	0.10
Madison, Wis	38,378	4.77	100	100	102.0	99.0	101.0	106.0	102.0	102.0	105	0.12[10]	0.09[10]	0.06[10]
Waltham, Mass	31,000	2.23	98	100	63.8	63.2	67.2	65.5	65.5	65.0	70	0.22	0.15	0.15
San Francisco, Cal.[9]	506,676	39.31	100	100	71.4	70.3	63.7	62.2	58.2	65.2	65	0.40[10]	0.33[10]	0.30[10]

[1] Rates averaged to nearest cent only.
[2] Private company.
[3] Includes supply from both municipal and private works.
[4] Population for July 1, 1920.
[5] Data given on basis of population of "Springfield District" only.
[6] Consumption in Yonkers high on account of sugar refineries and other manufacturing plants.
[7] For 1923.
[8] Average for four years 1920–1923.
[9] Weighted average.
[10] Includes service charge. Assumed size of meter for stated quantities: Domestic ¾ inch; intermediate 2 inches, manufacturing, 6 inches.
[11] Rates for high pressure service are one-third higher.
[12] Rate for purposes other than manufacturing.
[13] Rate for manufacturing purposes.

this standard classification of quantities of the New England Water Works Association.

	GALLONS PER MONTH	EQUIVALENT GALLONS PER		
		Day	Quarter	Year
Domestic service	25,000	830	75,000	300,000
Intermediate service	250,000	8,300	750,000	3,000,000
Manufacturing service	2,500,000	83,000	7,500,000	30,000,000

In determining the relative water rates, allowance has been made for the "service charge" in those cities making use of it, the service charge being based upon a $\frac{3}{4}$ inch meter for the domestic service; 2-inch meter for the intermediate service and 6-inch meter for the manufacturing service.

The data contained in table 1 were then plotted on different forms of cross-section paper in studying trends, using both natural and logarithmic scales. As an aid to judgment there were also prepared figures 1 and 2, showing the increase in per capita consumption with growth in population for different cities, utilizing the available record extending in many cases over long periods of years and noting upon these diagrams the gradual increase in per cent of services metered. These lines were of material assistance in determining trends. The trend line shown upon the two diagrams was taken from figure 3.

In figure 3 are shown the "Apparent trends in relation of per capita water consumption to population, for cities with different water rates," the record of each city being plotted with the name of the city beside it and the prevailing water rate per thousand gallons, for manufacturing service for assumed quantities of 2,500,000 gallons per month. Three lines showing trends were finally drawn, correlating the entire evidence, the heavy line in the center corresponding to water rates of from 10 to 13 cents per thousand gallons for manufacturing quantities (2.5 million gallons per month) and dotted lines covering rates below 10 cent per thousand gallons and rates above 13 cents per thousand gallons.

In figure 4 are shown the "Apparent trends in relation of per capita consumption to water rates," in three groups covering domestic rates, intermediate rates and manufacturing rates as heretofore defined, the name of the city being shown before each record; and in figure 5 are assembled the combined results shown in figure 4 in

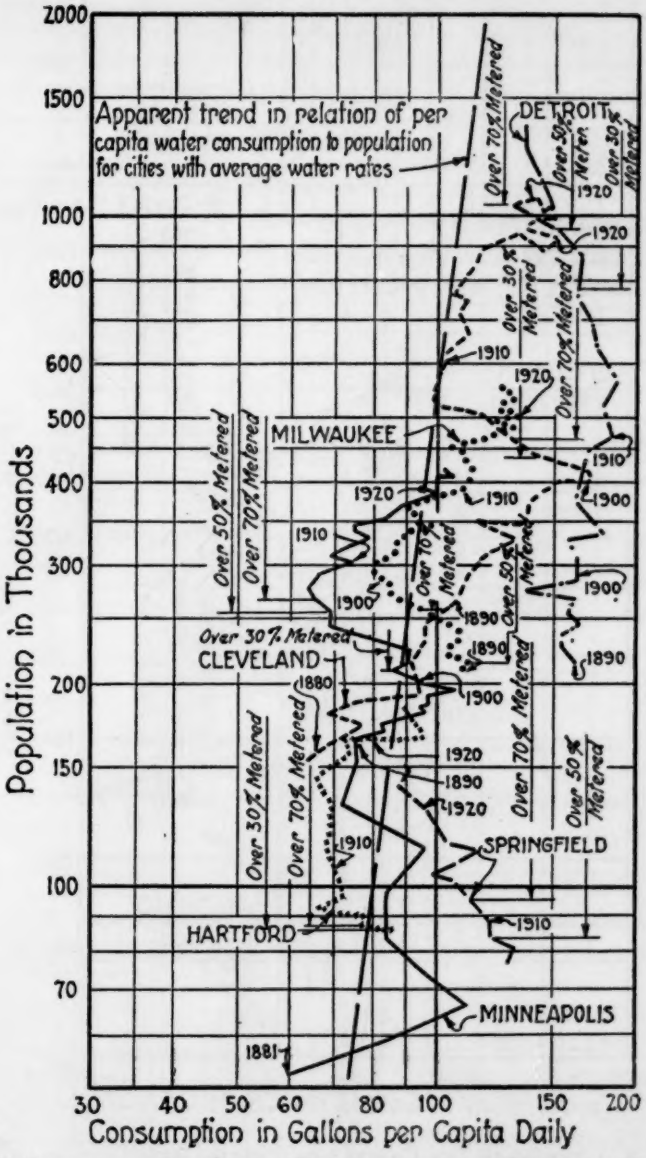

FIG. 1. INCREASE IN PER CAPITA CONSUMPTION WITH GROWTH IN POPULATION FOR DIFFERENT CITIES

Note: The existing water rates (manufacturing) for the cities plotted are as follows:

	cents per 1000 gallons		cents per 1000 gallons
Detroit	6	Minneapolis	8
Cleveland	8	Hartford	10
Milwaukee	9	Springfield	7

These rates are average rates for an assumed quantity of 2,500,000 gallons per month.

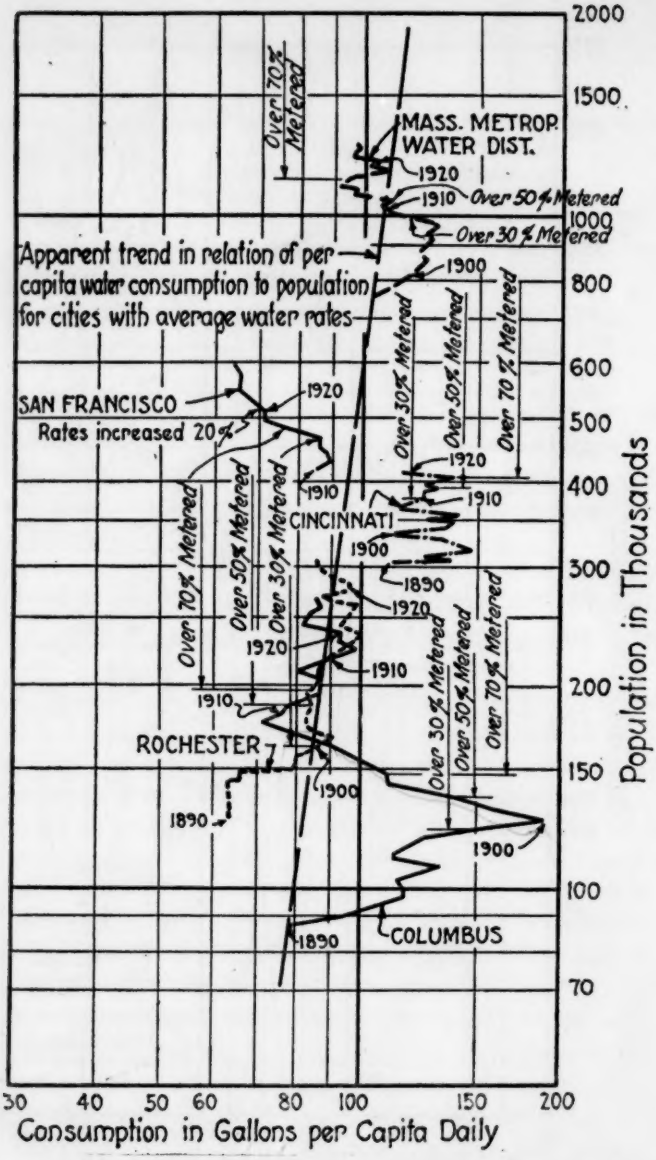

FIG. 2. INCREASE IN PER CAPITA CONSUMPTION WITH GROWTH IN POPULATION FOR DIFFERENT CITIES

Note: The existing water rates (manufacturing) for the cities plotted are as follows:

	cents per 1000 gallons		*cents per 1000 gallons*
Massachusetts Metropolitan Water District	18	Columbus	15
Cincinnati	16	Rochester	15
		San Francisco	30

These rates are average rates for an assumed quantity of 2,500,000 gallons per month.

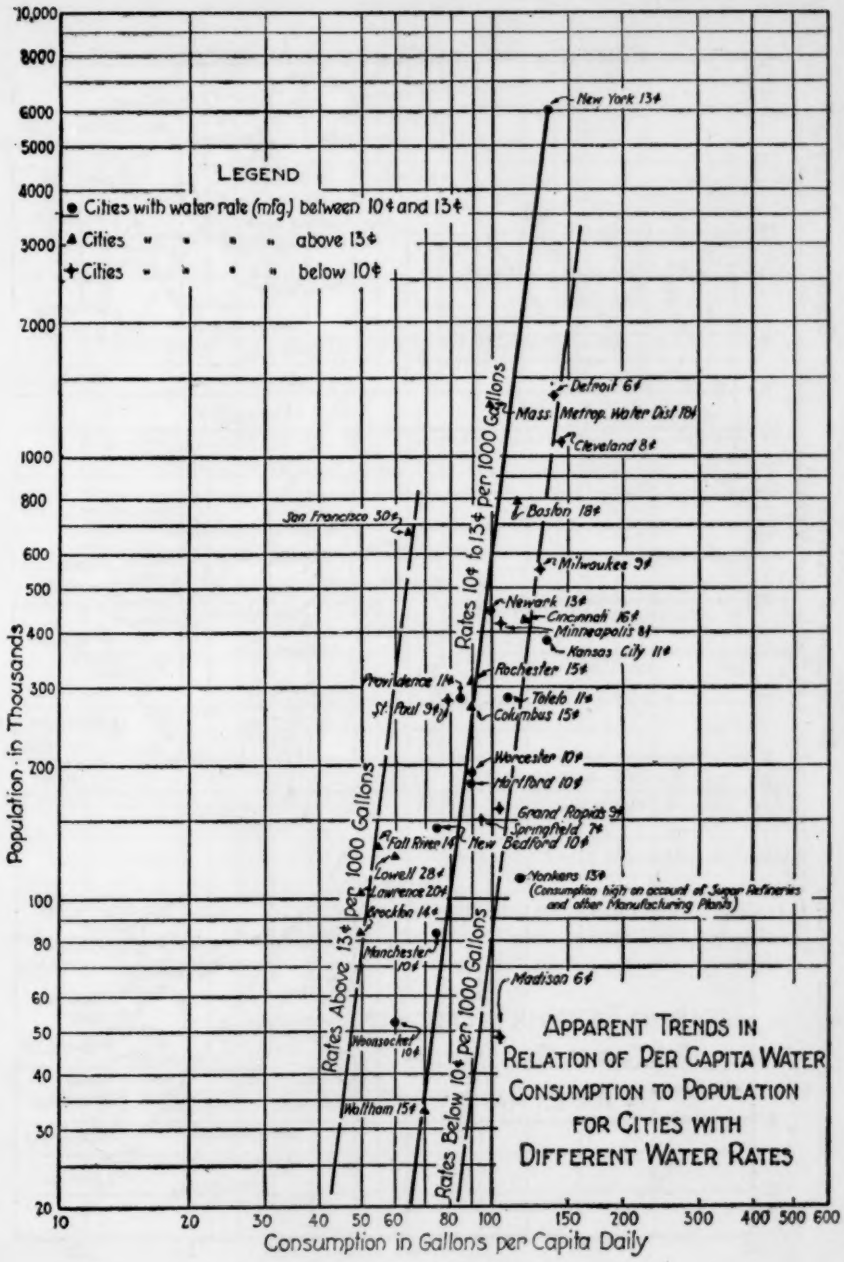

FIG. 3

The prices shown for the cities plotted indicate the average rates per 1000 gallons for an assumed quantity of 2,500,000 gallons per month for manufacturing pruposes.

Populations are as estimated for 1924.

Per capita water consumptions are probable present safe amounts, estimated from records of 1920 to 1924 inclusive.

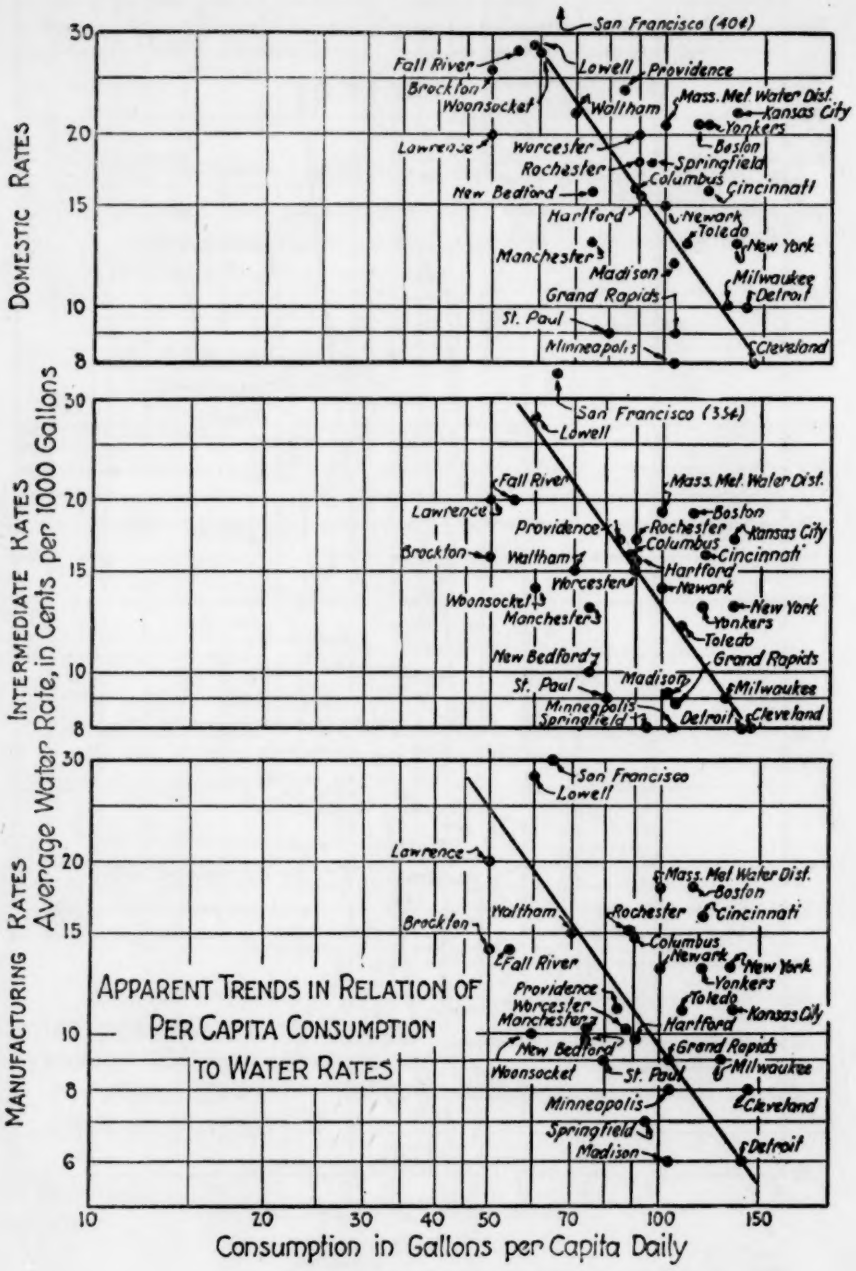

FIG. 4

The per capita consumption for the cities shown are probable present safe amounts estimated from records of 1920 to 1924 inclusive.

The water rates are the average rates for assumed quantities of 25,000 gallons per month for domestic rates; and 250,000 gallons per month for intermediate rates and 2,500,000 gallons per month for manufacturing rates.

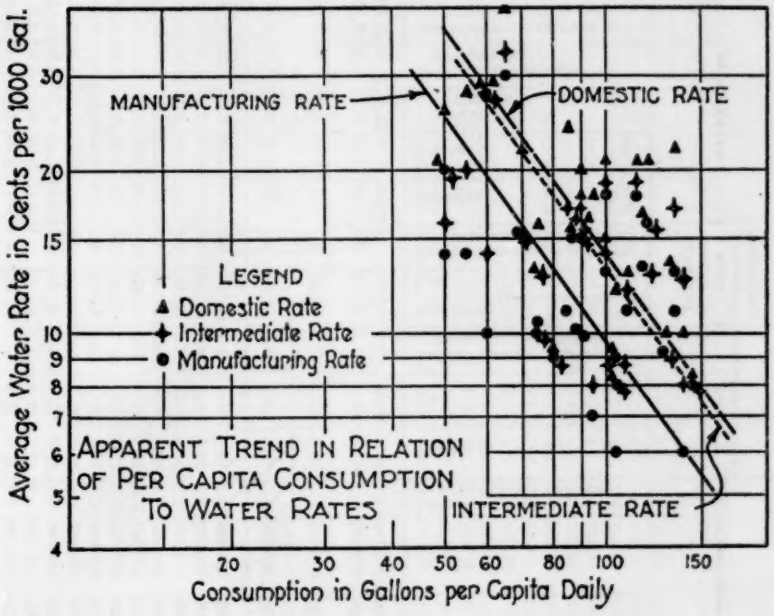

FIG. 5

The points plotted represent the rates of per capita consumption for 30 different cities, plotted in each case for the domestic, intermediate and manufacturing rates of the city.

The per capita consumption are probable present safe amounts, estimated from records of 1920 to 1924 inclusive.

The domestic, intermediate and manufacturing rates are the average rates for assumed quantities of 25,000 gallons, 250,000 gallons and 2,500,000 gallons per month, respectively.

TABLE 2

Effect of growth in population on water consumption for various cities

		CITY	PERIOD OF YEARS		PER CENT OF SERVICES METERED		POPULATION			TOTAL CONSUMPTION (M.G.D.)			PER CAPITA CONSUMPTION (GALLONS PER DAY)			METER RATES				
			Years taken	Length of period	Beginning	End	Beginning	End	Annual increase in per cent (compounded annually)	Beginning	End	Annual increase in per cent (compounded annually)	Beginning	End	Annual increase in per cent (compounded annually)	Minimum charge		Domestic rate per 1000 gallons	Intermediate rate per 1000 gallons	Manufacturing rate per 1000 gallons
																Monthly	Annual			
Group 1 (present population over 1,000,000)	1	Detroit, Mich.	1920–1924	4	97	99	1,066,000	1,372,000	6.6	152.0	184.0	4.9	143	134	−1.5	$0.42	$5.00	$0.10	$0.08	$0.06
	2	Massachusetts Metropolitan district	1913–1924	11	58	95	1,110,000	1,300,000	1.4	103.8	124.1	1.7	94	95	0.1	0.67	8.00	0.21	0.19	0.18
	3	Cleveland, O.	1908–1924	16	94	98	519,000	1,074,000	4.7	52.1	151.2	6.9	100	141	2.2	0.50	6.00	0.08	0.08	0.08
		Straight average for Group 1.....		10	83	97	898,000	1,249,000	4.2	102.6	153.1	4.5	112	123	0.3	0.53	6.33	0.13	0.12	0.11
Group 2 (present population between 250,000 and 1,000,000)	4	Boston, Mass.	1913–1924	11	41	94	733,000	788,000	0.6	79.4	87.7	0.9	108	111	0.3	0.67	8.00	0.21	0.19	0.18
	5	San Francisco, Cal.	1919–1924	5	100	100	565,000	610,000	1.6	35.7	39.3	1.9	63	64	0.4	0.78	9.36	0.40	0.33	0.30
	6	Milwaukee, Wis.	1901–1924	23	89	99	300,000	550,000	2.7	24.0	69.0	4.7	80	125	2.0	0.17	2.00	0.10	0.09	0.09
	7	Newark, N. J.	1917–1924	7	88	96	418,000	446,000	1.0	45.6	43.6	−0.6	109	98	−1.5	0.50	6.00	0.15	0.14	0.13
	8	Cincinnati, O.	1914–1924	10	61	100	397,000	425,000	0.7	50.8	48.9	−0.4	128	115	−1.1	0.40	4.80	0.16	0.16	0.16
	9	Minneapolis, Minn.	1908–1924	16	76	100	277,000	417,000	2.6	17.8	42.8	5.6	64	102	2.9	0.33	4.00	0.08	0.08	0.08
	10	New Orleans, La.	1918–1924	6	100	100	389,000	412,000	1.0	33.2	45.4	5.4	85	110	4.3	0.25	3.00	0.11	0.09	0.07
	11	Kansas City, Mo.	1916–1924	8	70	83	315,000	384,000	2.5	32.7	48.3	5.0	104	126	2.4	0.70	8.40	0.22	0.17	0.11
	12	Rochester, N. Y.	1908–1924	16	87	99	202,000	309,000	2.7	17.6	26.4	2.6	87	86	−0.1	0.50	6.00	0.18	0.17	0.15
	13	Providence, R. I.	1902–1924	22	84	95	198,000	284,000	1.6	11.6	23.6	3.3	58	83	1.6	0.67	8.00	0.24	0.17	0.11
	14	Toledo, O.	1910–1924	14	85	100	168,000	283,000	3.8	15.6	29.0	4.5	93	102	0.7	0.71	8.50	0.13	0.12	0.11
	15	St. Paul, Minn.	1914–1924	10	85	99	225,000	280,000	2.2	13.5	20.4	4.2	60	73	2.0	0.30	3.60	0.09	0.09	0.09
	16	Columbus, O.	1910–1924	14	91	99	182,000	270,000	2.8	13.8	23.2	3.8	76	86	0.9	0.40	4.80	0.16	0.16	0.15
		Straight average for Group 2.....		12	81	97	336,000	420,000	2.0	30.1	42.1	3.1	86	99	1.1	0.49	5.88	0.17	0.15	0.13

Straight average for Group 2	**12**	**81**	**97**	**336,000**	**420,000**	**2.0**	**30.1**	**42.1**	**3.1**	**86**	**99**	**1.1**	**0.49**	**5.88**	**0.17**	**0.15**	**0.13**

Group 3 (present population between 100,000 and 250,000)	17	San Antonio, Tex.	1913–1924	11	27	60	120,000	210,000	5.2	12.6	23.0	5.7	105	109	0.4	0.80	9.60			
	18	Worcester, Mass.	1896–1924	28	93	98	103,000	192,000	2.2	6.1	16.3	3.6	60	84	1.3	0.33	4.00	0.20	0.15	0.10
	19	Hartford, Conn.	1905–1924	19	99	100	91,000	182,000	3.7	6.2	16.2	5.2	69	89	1.3			0.16	0.16	0.10
	20	Dayton, O.	1917–1924	7	81	87	141,000	170,000	2.8	12.7	16.7	3.9	90	98	1.2	0.55	6.60	0.13	0.09	0.07
	21	Grand Rapids, Mich.	1915–1924	9	75	100	125,000	160,000	2.8	10.5	15.9	4.8	84	99	1.9	0.67	8.00	0.09	0.09	0.09
	22	Springfield, Mass.	1913–1924	11	94	99	99,000	151,000	3.9	10.7	13.5	2.1	108	89	−1.8	0.67	8.00	0.18	0.08	0.07
	23	New Bedford, Mass.	1914–1924	10	96	93	108,000	145,000	3.0	7.4	9.7	2.7	69	67	−0.3	0.42	5.00	0.16	0.10	0.10
	24	Fall River, Mass.	1900–1924	24	94	100	108,000	131,000	0.9	3.8	6.8	2.5	35	52	1.7			0.28	0.20	0.14
	25	Lowell, Mass.	1909–1924	15	77	90	105,000	125,000	1.2	5.2	6.5	1.5	50	52	0.3			0.28	0.28	0.28
	26	Yonkers, N. Y.	1909–1924	15	100	100	76,000	110,000	2.5	7.6	13.4	3.8	100	122	1.3	0.67	8.00	0.21	0.13	0.13
	27	Lawrence, Mass.	1905–1924	19	88	97	69,000	103,000	2.1	3.0	4.6	2.3	43	45	0.3	0.58	7.00	0.20	0.20	0.20
	28	Somerville, Mass.	1913–1924	11	61	94	83,000	101,000	1.8	6.0	7.8	2.4	72	77	0.6	0.50	6.00	0.16	0.16	0.12
		Straight average for Group 3		**15**	**82**	**93**	**102,000**	**148,000**	**2.7**	**7.6**	**12.5**	**3.4**	**74**	**82**	**0.7**	**0.58**	**6.91**	**0.19**	**0.15**	**0.13**
Group 4 (present population between 25,000 and 100,000)	29	Brockton, Mass.	1911–1924	13	100	100	69,000	84,000	1.5	2.7	4.2	3.5	39	50	1.9			0.26	0.16	0.14
	30	Manchester, N. H.	1904–1924	20	70	85	62,000	83,000	1.5	3.1	6.4	3.7	50	77	2.2	0.67	8.00	0.13	0.13	0.10
	31	Malden, Mass.	1913–1924	11	99	99	48,000	53,000	0.9	2.23	2.86	2.3	46	54	1.4	0.58	7.00	0.21	0.20	0.19
	32	Quincy, Mass.	1913–1924	11	86	91	36,000	53,000	3.6	2.7	4.4	4.5	76	82	0.7	1.17	14.00	0.31	0.24	0.19
	33	Woonsocket, R. I.	1893–1923	30	86	96	23,000	51,000	2.7	0.6	3.1	5.6	24	60	3.1	0.83	10.00	0.28	0.14	0.10
	34	Madison, Wis.	1897–1924	27	89	100	18,000	48,000	3.7	0.8	4.8	6.9	44	102	3.2			0.12	0.09	0.06
	35	Chelsea, Mass.	1913–1924	11	98	100	36,000	47,000	2.5	2.88	3.55	1.9	80	76	−0.5	0.50	6.00	0.15	0.15	0.15
	36	Medford, Mass.	1913–1924	11	100	100	26,000	46,000	5.3	1.2	2.4	6.5	48	53	0.9	0.50	6.00	0.20	0.16	0.16
	37	Everett, Mass.	1913–1924	11	40	89	37,000	44,000	1.6	2.4	4.5	5.9	65	102	4.2	0.50	6.00	0.16	0.15	0.12
	38	Taunton, Mass.	1905–1923	18	46	88	28,000	37,000	1.6	1.9	3.6	3.6	69	99	2.0	0.75	9.00	0.25	0.18	0.11
	39	Waltham, Mass.	1919–1924	5	91	100	31,000	33,000	1.2	1.9	2.2	3.0	61	66	1.6	0.83	10.00	0.22	0.15	0.15
	40	Revere, Mass.	1913–1924	11	50	87	21,000	31,000	3.6	1.39	2.29	4.7	67	74	0.9	0.83	10.00	0.19	0.15	0.15
	41	Watertown, Mass.	1913–1924	11	100	100	14,000	26,000	5.8	0.87	1.66	6.1	62	63	0.2	0.83	10.00	0.33	0.30	0.22
		Straight average for Group 4		**15**	**81**	**95**	**35,000**	**49,000**	**2.7**	**1.9**	**3.5**	**4.5**	**56**	**74**	**1.7**	**0.73**	**8.73**	**0.22**	**0.17**	**0.14**

TABLE 2—*Continued*

		CITY	PERIOD OF YEARS		PER CENT OF SERVICES METERED		POPULATION			TOTAL CONSUMPTION (M.G.D.)			PER CAPITA CONSUMPTION (GALLONS PER DAY)			METER RATES				
			Years taken	Length of period	Beginning	End	Beginning	End	Annual increase in per cent (compounded annually)	Beginning	End	Annual increase in per cent (compounded annually)	Beginning	End	Annual increase in per cent (compounded annually)	Minimum charge		Domestic rate per 1000 gallons	Intermediate rate per 1000 gallons	Manufacturing rate per 1000 gallons
																Monthly	Annual			
Group 5 (present population below 25,000)	42	Arlington, Mass.	1913–1924	11	100	100	13,000	24,000	5.8	0.79	1.40	5.3	63	59	−0.5	1.25	15.00	0.20	0.16	0.14
	43	Melrose, Mass.	1913–1924	11	100	100	17,000	19,000	1.0	1.14	1.25	0.9	68	64	−0.5	0.75	9.00	0.22	0.20	0.20
	44	Winthrop, Mass.	1913–1924	11	100	100	11,000	18,000	4.6	0.69	0.97	3.2	60	55	−0.7	1.00	12.00	0.24	0.24	0.24
	45	Milford, Mass.	1910–1924	14	57	89	15,000	16,000	0.5	0.8	0.9	0.9	51	56	0.7	1.00	12.00	0.53	0.25	0.21
	46	Belmont, Mass.	1913–1924	11	100	100	6,300	14,000	7.5	0.46	0.89	6.2	73	64	−1.2	0.83	10.00	0.24	0.20	0.20
	47	Milton, Mass.	1913–1924	11	100	100	8,500	11,000	2.3	0.33	0.54	4.6	39	47	1.7	1.00	12.00	0.33	0.33	0.33
	48	Swampscott, Mass.	1913–1924	11	100	100	6,600	8,400	2.2	0.42	0.73	5.2	63	87	3.0	0.92	11.00	0.40	0.40	0.40
	49	Stoneham, Mass.	1913–1924	11	87	100	7,800	8,200	0.5	0.41	0.60	3.5	53	73	3.0	0.83	10.00	0.43	0.32	0.26
	50	Lexington, Mass.	1913–1924	11	79	100	5,400	7,000	2.4	0.36	0.45	2.1	67	64	−0.4	1.00	12.00	0.30	0.22	0.20
	51	Nahant, Mass.	1913–1924	11	60	94	1,400	1,600	1.2	0.17	0.20	1.5	123	126	0.2	0.83	10.00	0.25	0.25	0.25
		Straight average for Group 5.....		11	88	98	9,200	13,000	2.8	0.56	0.79	3.3	66	70	0.5	0.94	11.30	0.31	0.26	0.24

Group 6. (Massachusetts Metropolitan Water District)	4	Boston, Mass.	1913–1924	11	41	94	733,000	788,000	0.6	79.4	87.7	0.9	108	111	0.3	0.67	8.00	0.21	0.19	0.18
	28	Somerville, Mass.	1913–1924	11	61	94	83,000	101,000	1.8	6.0	7.8	2.4	72	77	0.6	0.50	6.00	0.16	0.16	0.12
	31	Malden, Mass.	1913–1924	11	99	99	48,000	53,000	0.9	2.23	2.86	2.3	46	54	1.4	0.58	7.00	0.21	0.20	0.19
	32	Quincy, Mass.	1913–1924	11	86	91	36,000	53,000	3.6	2.7	4.4	4.5	76	82	0.7	1.17	14.00	0.31	0.24	0.19
	35	Chelsea, Mass.	1913–1924	11	98	100	36,000	47,000	2.5	2.88	3.55	1.9	80	76	−0.5	0.50	6.00	0.15	0.15	0.15
	36	Medford, Mass.	1913–1924	11	100	100	26,000	46,000	5.3	1.2	2.4	6.5	48	53	0.9	0.50	6.00	0.20	0.16	0.16
	37	Everett, Mass.	1913–1924	11	40	89	37,000	44,000	1.6	2.4	4.5	5.9	65	102	4.2	0.50	6.00	0.16	0.15	0.12
	40	Revere, Mass.	1913–1924	11	50	87	21,000	31,000	3.6	1.39	2.29	4.7	67	74	0.9	0.83	10.00	0.19	0.15	0.15
	41	Watertown, Mass.	1913–1924	11	100	100	14,000	26,000	5.8	0.87	1.66	6.1	62	63	0.2	0.83	10.00	0.33	0.30	0.22
	42	Arlington, Mass.	1913–1924	11	100	100	13,000	24,000	5.8	0.79	1.40	5.3	63	59	−0.5	1.25	15.00	0.20	0.16	0.14
	43	Melrose, Mass.	1913–1924	11	100	100	17,000	19,000	1.0	1.14	1.25	0.9	68	64	−0.5	0.75	9.00	0.22	0.20	0.20
	44	Winthrop, Mass.	1913–1924	11	100	100	11,000	18,000	4.6	0.69	0.97	3.2	60	55	−0.7	1.00	12.00	0.24	0.24	0.24
	46	Belmont, Mass.	1913–1924	11	100	100	6,300	14,000	7.5	0.46	0.89	6.2	73	64	−1.2	0.83	10.00	0.24	0.20	0.20
	47	Milton, Mass.	1913–1924	11	100	100	8,500	11,000	2.3	0.33	0.54	4.6	39	47	1.7	1.00	12.00	0.33	0.33	0.33
	48	Swampscott, Mass.	1913–1924	11	100	100	6,600	8,400	2.2	0.42	0.73	5.2	63	87	3.0	0.92	11.00	0.40	0.40	0.40
	49	Stoneham, Mass.	1913–1924	11	87	100	7,800	8,200	0.5	0.41	0.60	3.5	53	73	3.0	0.83	10.00	0.43	0.32	0.26
	50	Lexington, Mass.	1913–1924	11	79	100	5,400	7,000	2.4	0.36	0.45	2.1	67	64	−0.4	1.00	12.00	0.30	0.22	0.20
	51	Nahant, Mass.	1913–1924	11	60	94	1,400	1,600	1.2	0.17	0.20	1.5	123	126	0.2	0.83	10.00	0.25	0.25	0.25
		Straight average for Group 6.....		11	83	97	62,000	72,000	3.0	5.8	6.9	3.8	69	74	0.7	0.81	9.67	0.25	0.22	0.21
		Massachusetts Metropolitan district	1913–1924	11	58	95	1,110,000	1,300,000	1.4	103.8	124.1	1.7	94	95	0.1			0.21	0.19	0.18
Group 7 (cities with small per cent of metering)	52	New York City, N. Y.	1920–1924	4	27	25	5,664,000	6,015,000	1.5	734.9	789.2	1.7	130	131	0.2			0.13	0.13	0.13
	53	St. Louis, Mo.	1912–1924	12	7	8	711,000	811,000	1.1	83.5	113.1	2.6	120	140	1.3	0.17	2.00	0.17	0.10	0.07
	54	Indianapolis, Ind.	1910–1924	14	11	23	237,000	362,000	3.1	19.3	32.4	3.8	81	90	0.8	1.40	16.80	0.19	0.16	0.09
		Straight average for Group 7.....		10	15	19	2,204,000	2,396,000	1.9	279.2	311.6	2.7	110	120	0.8	0.78	9.40	0.16	0.13	0.10

detail, for each of the three groups (domestic, intermediate and manufacturing rates).

In this diagram, figure 5, are shown all of the records plotted in the previous figure, and the three trend lines.

In table 5 have been assembled, for purposes of comparison, the average per capita water consumption for cities of different sizes,

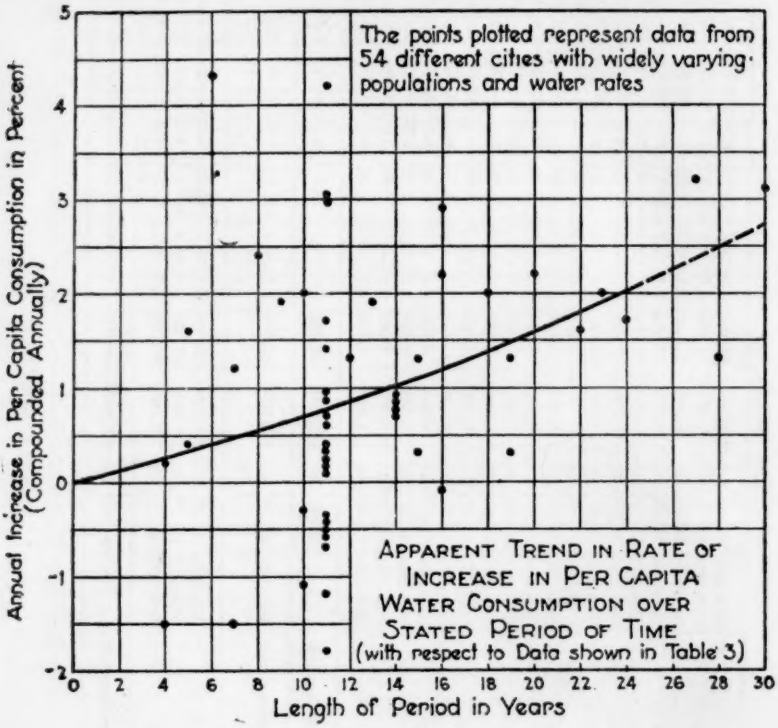
The points plotted represent data from 54 different cities with widely varying populations and water rates
Annual Increase in Per Capita Consumption in Percent (Compounded Annually)
APPARENT TREND IN RATE OF INCREASE IN PER CAPITA WATER CONSUMPTION OVER STATED PERIOD OF TIME (with respect to Data shown in Table 3)
Length of Period in Years
5
4
3
2
1
0
-1
-2
0 2 4 6 8 10 12 14 16 18 20 22 24 26 28 30

FIG. 6

grouped according to water rates. This table summarizes the trends shown in figure 3.

The conclusions drawn from these several tables and figures will be stated further on after submitting another table (table 2) showing an independent analysis of evidence which has been prepared from reports and other materials available to the author, which is of interest as showing individual characteristics in different cities, but with respect to which the conditions vary to such an extent as to make it impossible to include all of them in the original data submitted in table 1.

In table 2 are shown the further data referred to, upon the effect of growth in population on water consumption for various cities. There are given the name of the city, the period of years of record, the comparisons in per capita consumption being based upon the difference in record for the beginning and the end of said period of years; the per cent of services metered, both at the beginning and the end of the period; the population at the beginning and end of the period, and

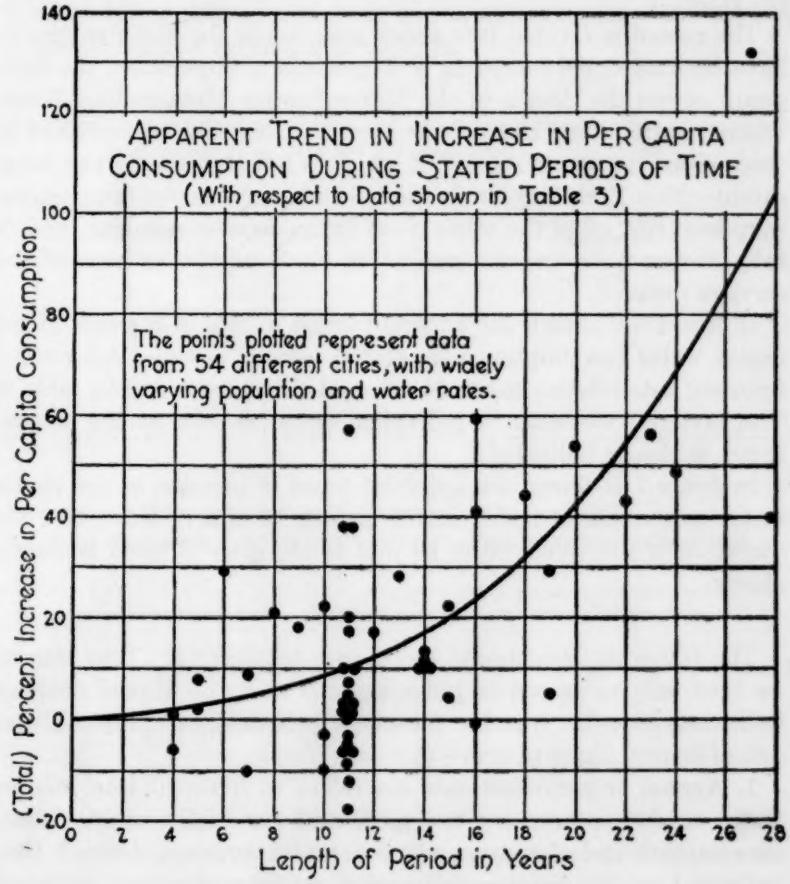

FIG. 7

the equivalent annual rate of increase in per cent, compounded annually, over the period of years stated; the total water consumption in million gallons daily, at the beginning and end of the period, with the resulting annual per cent of increase (compounded annually); the per capita water consumption in gallons per day at the beginning and end of the period; and the annual percentage of increase or decrease compounded annually; and finally the meter rates prevail-

ing in the year 1924 in the cities cited—the minimum charge in monthly and annual terms, and the rates per thousand gallons for domestic, intermediate and manufacturing service as heretofore defined (domestic consumption 25,000 gallons per month, intermediate 250,000 gallons per month, manufacturing 2,500,000 gallons per month). The latter statement of rates is merely for comparative purposes, to give indication of the general amount and variation in the rates.

The record is divided into seven groups and the first five groups have been arranged according to magnitude of population; the sixth group covers the details of the Massachusetts Metropolitan Water District surrounding Boston; the seventh group covers the record of three cities the water service of which is not metered to any large extent—New York City, St. Louis and Indianapolis—for comparative purposes only, all of the other cities being, broadly speaking, nearly fully metered, having in general upwards of 80 per cent of the services metered.

In figure 6 is shown the apparent trend in rate of increase in per capita water consumption over stated periods of time, determined from the data relating to the 54 different cities, contained in table 2. The material variation in individual cases, as well as the general trend, is clearly indicated.

In figure 7 is shown the apparent trend in increase in per capita water consumption during stated periods of time. Here, too, the variation in individual cities as well as the general trend is clearly shown.

CONCLUSIONS

The following conclusions are drawn tentatively. They are to be used only as an aid to judgment and as an additional criterion indicating apparent trends. Adequate local data, carefully analyzed are, of course, likely to prove more significant.

1. Annual or periodical data assembled at five-year intervals are badly needed, concerning the gross and per capita annual water consumption and the gross and per capita revenue derived from industrial service, commercial service, public service and domestic service.

It will probably prove advantageous to adopt the New England Water Works Association scale or some similar scale, to simplify comparison, but if, as some operators and engineers have thought, the difference in metered water scales in different parts of the country

should appear prohibitive, the comparison can still be made within the four groups first stated, the two big important groups being, of course, the large industrial service which varies with the condition of business, and the domestic service which is relatively stable—the commercial service and the public water service being relatively small and constant in amount.

2. The average increase in per capita daily water consumption with increase in population, appears to be about 10 per cent of the increase in population, as indicated in table 3.

TABLE 3

Variations in per capita water consumption corresponding to given variations in populations from data for 30 representative cities shown in table 1 and figure 3

INCREASE IN POPULATION	INCREASE IN PER CAPITA WATER CONSUMPTION
per cent	*per cent*
20	2
40	4
60	6
80	8
100	9

TABLE 4

Variations in per capita consumption corresponding to given variations in water rates, from data from 30 representative cities, shown in table 1 and figures 4 and 5

INCREASE IN RATES	DECREASE IN CONSUMPTION
per cent	*per cent*
20	13
40	22
60	29
80	35
100	40

3. The average decrease in per capita consumption of water, with increase in rates, is indicated by the figures in table 4.

4. With water rates for large industrial services of from 10 to 13 cents per thousand gallons, the average per capita water consumptions appear to increase from 67 g.p.d. for populations of 25,000 to 73 g.p.d. for 50,000, 77 g.p.d. for 75,000, 80 g.p.d. for 100,000, 90

g.p.d. for 250,000, 98 g.p.d. for 500,000, and 107 g.p.d. for 1,000,000 population.

The relative per capita consumptions increase with decrease in water rate and vice versa, as indicated by table 5, thus for industrial water rates of less than 10 cents per thousand gallons, the per capita consumption varies from 86 g.p.d. for a population of 25,000 to 103 for a population of 100,000 and 138 for a population of 1,000,000. Similarly the per capita consumptions for rates greater than 13 cents per thousand gallons decrease to 43, 52 and 70 g.p.d., all of which figures are comparable with those stated above as applying to industrial water service rates of 10 to 13 cents per thousand gallons, as shown in table 5.

TABLE 5

Average per capita water consumption for cities of different sizes, grouped according to water rates*

POPULATION OF CITY	PER CAPITA WATER CONSUMPTION (IN GALLONS PER DAY)		
	For cities with water rate (Manufacturing)		
	Below 10 cents per 1000 gallons	10 to 13 cents per 1000 gallons	Above 13 cents per 1000 gallons
25,000	86	67	43
50,000	94	73	48
75,000	99	77	50
100,000	103	80	52
250,000	116	90	59
500,000	126	98	64
750,000	132	103	67
1,000,000	138	107	70
2,000,000	150	117	76

* As indicated by curves drawn for 30 representative cities.

5. In table 2 the records of variation in annual rate of increase in per capita water consumption are shown for 54 cities, based upon variable periods of record. The latter records, which are believed to be not quite so comparable or significant as those already referred to, indicate the increases over stated period of years in population, total water consumption, and per capita daily water consumption—all given in amount and in per cent compounded annually. The annual increase in per capita consumption, in per cent compounded annually, and the total amount of such increase, over stated periods of time, are shown in figures 6 and 7, respectively.

Figure 6 appears to indicate an average annual rate of increase-in-per cent in per capita water consumption for the 54 cities cited, of 0.75 per cent per decade; that is, that the rate of increase for the first ten years averages 0.75 per cent; for the twenty-year period, 1.5 per cent; and for the thirty-year period 2.75 per cent.

RECORDING THE HYDROGEN ION CONCENTRATION OF POTABLE WATER

By Henry C. Parker[1] and John R. Baylis[2]

INTRODUCTION

Wolman and annan[3] were the first to call attention to the value of hydrogen ion concentration in water treatment. Since the appearance of their article the influence of hydrogen ion concentration on the chemical reactions involved in the treatment of public water supplies has been well established, and no water purification plant using a coagulant before filtration can be operated at its greatest efficiency without a fairly good knowledge of such influence. When a chemical compound, such as aluminum sulfate or lime, is added to the water there is always produced a change in the hydrogen ion concentration. In certain cases the measurement of this change will actually indicate the amount of chemical applied.

The application of lime is generally made for the direct purpose of causing a change in hydrogen ion concentration or pH. Thus, in the "iron and lime" method, the purpose of the lime is to bring the water to approximately that pH at which maximum precipitation of iron hydroxide will take place. In those cases where lime is added for softening purposes, or to prevent corrosion, the purpose is the same—namely, to alter the hydrogen ion concentration. In the application of alum, however, the change in pH is usually incidental and may or may not be in such direction as to aid in the clarification.

It is quite generally recognized that, with alum, the isoelectric point and the maximum precipitation and clarification occur at a pH of between 5.5 and 6.0.[4] Several workers,[5] however, have found that,

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[2] Principal Sanitary Chemist, Water Department, Baltimore, Md.

[3] Wolman and Hannan, *Chemical & Metallurgical Engineering*, 24, April 17, 1921.

[4] Baylis, *J. Am. Water Works Assoc.*, 10, 373 (1923).
Theriault and Clark, *Pub. Health Reports*, Reprint No. 813.

[5] Norcom, *J. Am. Water Works Assoc.*, 11, 96 (1924).
Catlett, *J. Am. Water Works Assoc.*, 11, 887 (1924).
Hatfield, *J. Am. Water Works Assoc.*, 11, 554 (1924).

for certain waters, optimum conditions exist at pH values below and above these. The optimum condition for certain colored waters has been reported as low as a pH of 4.0, and for certain highly alkaline waters as high as 7.0. It has been found, however, that the majority of our natural waters have an optimum pH value between 5.5 and 6.5. The lower the amount of dissolved salts in the water and the less alum used in the precipitation, the more narrow becomes the favorable zone of precipitation and hence the more important the control of pH. It is evident, therefore, that, if the addition of alum caused the pH to fall sufficiently below 5.5, best results would be obtained by the addition of lime or other alkali to control the final value to a pH of 5.5–6. Conversely, it has been shown[4] that in certain cases economical results may be obtained by the use of acid with the alum to bring the water to the desired pH. The total alum required for clarification is usually determined by the color or turbidity.[6] That the alum usually required for clarification frequently changes the hydrogen concentration in the proper direction, and to such an extent that the zone of maximum clarification is roughly approached, is due more to favorable circumstances than to scientific management. In many water purification plants the alum dosage is undoubtedly used, partially to control the pH and partially for clarification, without any definite conception of the independent effect of the two factors. Using alum to control the pH may not be economical.

In case the optimum condition for alum clarification is secured, which leaves the effluent at a pH of 5.5–6.5, it is evident that further treatment is essential for the prevention of corrosion. It is apparently true that the "harder" waters cause less corrosion at these pH values and consequently it is possible to avoid complaints of "red water" even though no additional treatment is used. However, when the public learns that a properly treated water means a more palatable water, and that considerable savings would be effected in the cost of service pipes and, what is closer to the average household, in soap[7] the water works officials will necessarily have to give more consideration to such treatment.

Hydrogen ion measurements are thus essential, in a water purification plant, both for proper control of the factors affecting precipita-

[6] Pirnie, *J. Am. Water Works Assoc.*, **9**, 247 (1922).
[7] Barr, *J. Am. Water Works Assoc.*, **9**, 295 (1922).

tion and to supply a final product possessing the most favorable characteristics. It is evident that a record of hydrogen ion concentrations would therefore prove of undoubted value.

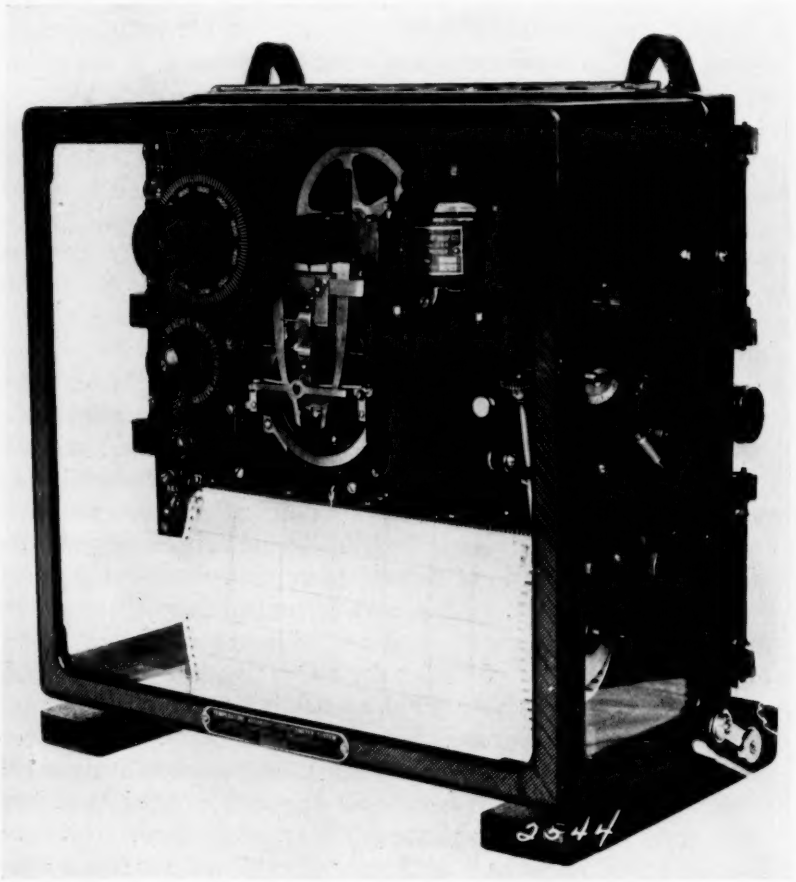

FIG. 1. RECORDING POTENTIOMETER

THE DEVELOPMENT OF SUITABLE ELECTRODES

The recording potentiometer shown in figure 1 has been developed for a number of years and has been employed in a large number of commercial applications. A greatly varied line of indicating and controlling instruments has also been available. To obtain a successful hydrogen ion record has been much less a problem of developing a

measuring instrument than of finding electrodes which will prove suitable in regard to being "fool proof" and requiring a small amount of expert attention.

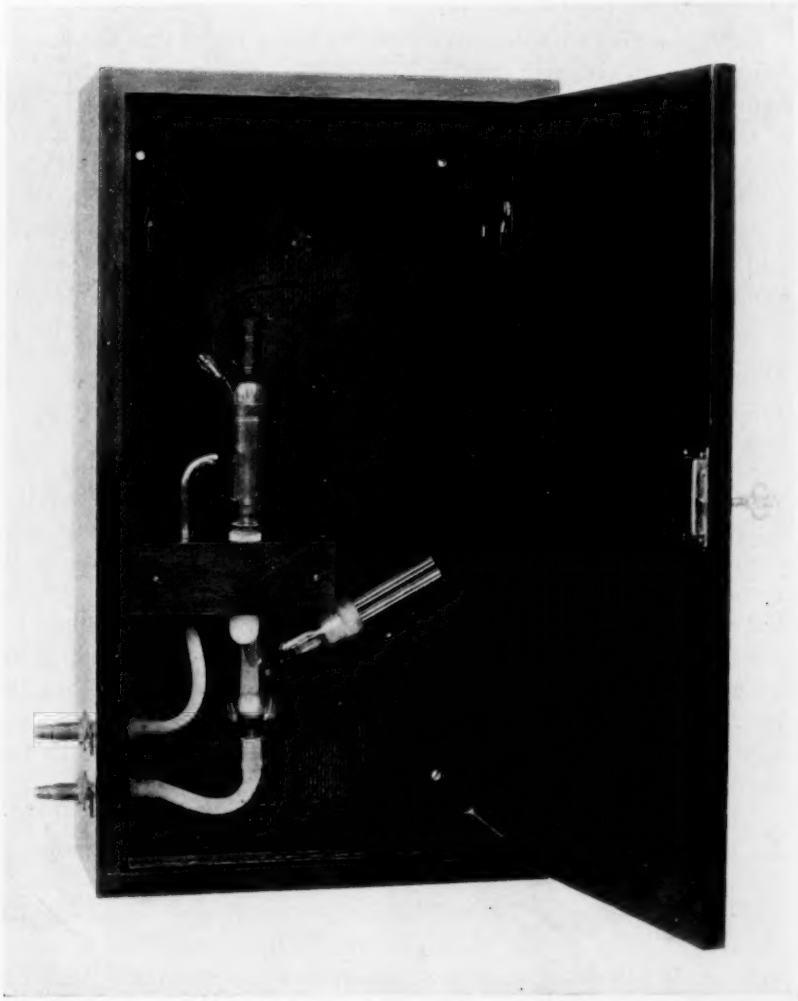

FIG. 2. MERCURY-CALOMEL HALF-CELL AND TUNGSTEN ELECTRODE

Several years have been spent in attempting to produce such electrodes and several new types have been developed. One of the most promising of the earlier electrodes was the aspirator type[8]

[8] Keeler, *J. Ind. Eng. Chem.*, **14**, 1010 (1922).

which was tested at the Montebello Filters, Baltimore Water Department. Sufficient accuracy was not obtained with this electrode, and too much expert attention was required in keeping the potassium chloride solution for the calomel cell flowing at the proper rate, in platinizing the electrodes, etc.

Experimenting with various electrodes it was found that the tungsten wire in an ordinary electric lamp would serve as an electrode in hydrogen ion measurements.[9] Later it was found that the addition of manganese sesquioxide in proximity to the tungsten, and a preliminary treatment in an alkaline buffer solution, would permit such electrodes to be used in more acid solutions and would increase their "life" and reproducibility.[10] Figure 2 shows the tungsten electrode and the calomel cell, the latter of which is another recent development.[11] The type of cell shown in this figure has been in use for about a year at the Montebello Filters and has proven far superior to any other type tested.

CARE REQUIRED BY THE APPARATUS

The attention required by the electrodes shown in figure 2 has been very much reduced. The calomel cell requires flushing and the introducing of fresh crystals of potassium chloride in the porous cup, approximately twice a week. The tungsten electrode has to be introduced into the cell about 24 hours before it is placed in service, but after it has reached equilibrium, it will give reliable readings for from two weeks to a month without any attention. Including the time required to take care of the recorder, such as oiling, filling the pen, renewing paper etc., the total attention required to obtain a continuous record of hydrogen ion concentration amounts to less than ten minutes a day.

The technique for making up the calomel cell is likewise simple. No standard solutions are required. The use of special grades of commercially purified mercury, electrolytic calomel and potassium chloride, in making up the cell, has been found to give a reproducibility considerably greater than that required for industrial measurements. A saturated solution of the potassium chloride is added to some of the mercury and calomel in the cell and, after shaking a few minutes, the cell is ready for service.

[9] Baylis, *J. Ind. Eng. Chem.*, **15**, 852 (1923).
[10] Parker, *J. Ind. Eng. Chem.*, **17**, 737 (1925).
[11] Parker and Dannerth, *J. Ind. Eng. Chem.*, **17**, 637 (1925).

THE FLOW TYPE QUINHYDRONE ELECTRODE[12]

By the addition of an adapter and the introduction of a gold electrode in place of the tungsten, the flow type cell shown in figure 2 may be converted into a quinhydrone electrode. The quinhydrone (purchased commercially or easily made) is introduced into the adapter in small silk bags which require renewing about twice a week. This electrode reaches equilibrium more quickly and is somewhat more reproducible than the tungsten electrode. It may be used advantageously through a range of 3.0 to 7.5 pH, while the tungsten electrode is suitable from about 5.0 to 12 pH. It seems probable that the former will prove the more suitable for measurements in the raw water or in the precipitation with alum while the latter will prove the more suitable for controlling the addition of lime at the higher pH values. The quinhydrone electrode has the advantage of a lower temperature coefficient and likewise requires but small attention. Both of the electrodes appear to be especially free from the so-called "poisons" which affect the hydrogen electrode. The electrodes have been tested in the city water supplies of Philadelphia and Baltimore and tests are in progress in other cities.

In cold water a larger surface of quinhydrone must be exposed, in order to give a sufficient rate of solubility. However, this is much more convenient to accomplish than to regulate a dropping solution to the proper rate. The flow through the cell is regulated to about one liter in four to five minutes.

INTERPRETATION OF THE READINGS

It is usually convenient to have the scale of the recorder read in volts. If a definite electrode is to be used and the temperature is compensated, a scale reading directly in pH units may be employed. The voltage readings may easily be interpreted in terms of pH by the use of the chart shown in figure 3. It is seen from this plot that temperature has some influence on the readings. In water works practice, however, temperature changes are so slow that these are easily taken into account.

When the readings are made in terms of pH they have a perfectly definite meaning and can be easily correlated with such factors as

[12] For bibliographies on the quinhydrone electrode see Biilmann, *Trans. Faraday Soc.*, **19**, 676 (1924) or LaMer and Baker, *J. Am. Chem. Soc.*, **44**, 1954 (1922).

color, turbidity, or proper clarification. These factors are much less obviously related to such quantities as "monocarbonate alkalinity" or "free CO_2" with which quantities many workers still prefer to approximate hydrogen ion concentrations. Moreover pH readings can be easily reproduced by other workers in the same field while the

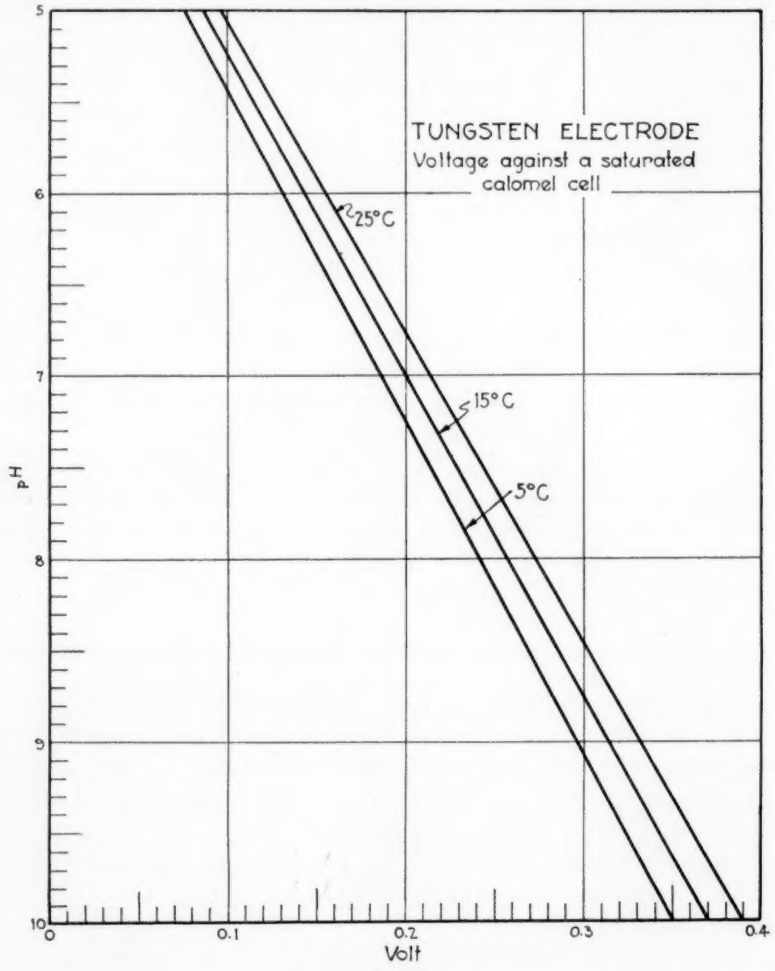

FIG. 3

quantities obtained by titration cannot be properly reproduced without a knowledge of the hydrolysable salts present.

The readings on the recorder may be interpreted in any terms desired. Thus, it is a simple matter to make an experimental

curve showing the relation between "alkalinity" and voltage of the electrodes, provided the water is being treated with a given chemical. The curve would vary somewhat with the alkalinity of the raw water, but changes in the latter would probably be slow enough to follow with ease. If the recorder readings are being used to control the addition of chemicals, either by signal lights or by an automatic valve, the setting of the control can be made to correspond to colorimetric pH measurements or to titration. This is easily accomplished by the "control point indicator" shown in front of the recorder in figure 1, since the "control point" can be readily adjusted to any value required. After two weeks to one month service the tungsten electrodes are found to drift very slowly towards higher voltages. If this drift is followed by changing the "control point" to correspond to the colorimetric pH or titration measurements, the electrodes may be used almost indefinitely.

ACCURACY OF THE MEASUREMENTS

From the experience gained with the tungsten electrodes thus far, it is evident that they are capable of an accuracy of close to 0.1 pH. This appears somewhat greater than the accuracy which can be obtained with colorimetric measurements upon potable water. When it is noted that a single small crystal of potassium chloride will frequently alter a colorimetric reading by 0.1 to 0.3 pH, that the color reading makes a fairly rapid shift of from 0.1 to 0.5 pH immediately after mixing, and that there is from 0.1 to 0.4 pH change produced in the reading by heating the tube with the hand (if the water is cold), a person becomes somewhat skeptical about the accuracy which is commonly claimed in colorimetric measurements. The authors made a series of colorimetric measurements on several samples of potable water using commercially purified dyes from two sources and commercial standards, as well as those freshly made up from buffer solutions. The average agreement in the measurements was not better than $\pm$ 0.2 pH. Dawson[13] has recently pointed out a source of error in the usual colorimetric method of measuring the pH of distilled water. Kohltoff[14] has also shown that considerable salt errors are present when measuring solutions poor in electrolytes by colorimetric measurements.

[13] *J. Phys Chem.*, **29**, 551 (1925).
[14] *Rec. trav. chim.*, **44**, 275 (1925).

From the authors' measurements with the tungsten electrode in potable water and from the frequent comparisons obtained with colorimetric measurements, the latter appear to give readings which average about 0.2 pH *high*. A possible explanation is found in the

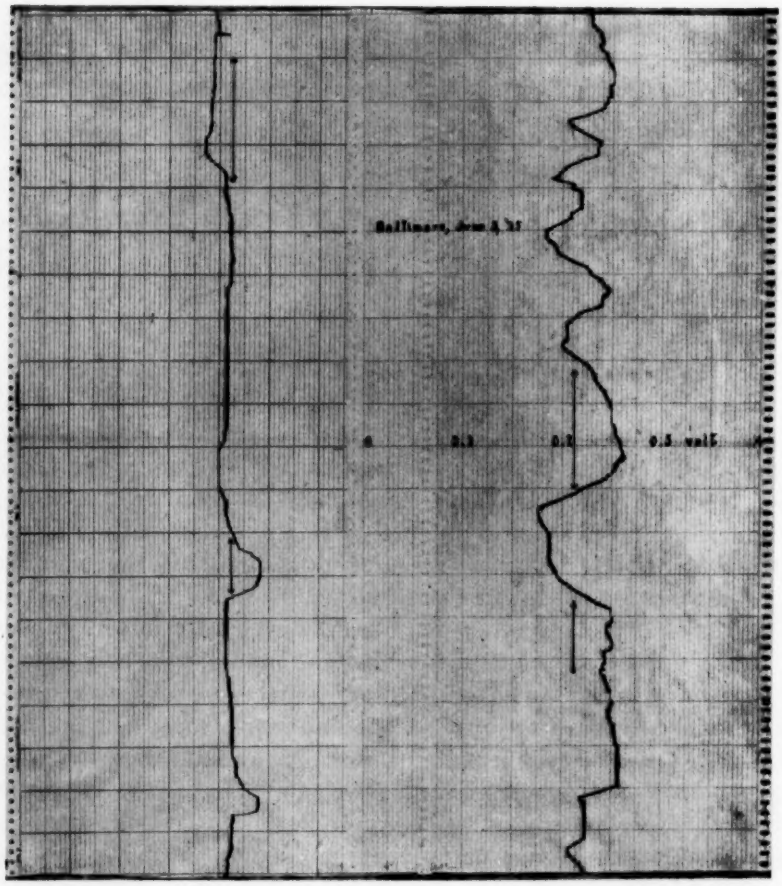

FIG. 4. H-ION RECORDS AT BALTIMORE

alkali which is usually added in making up the indicator solution. Even though the amount added is an equivalent and is supposed to form a neutral salt with the indicator, it is evident that such a salt would be highly hydrolyzed in solution and would be sufficient to cause errors in any slightly buffered medium.

In one experiment an alcoholic solution of an indicator was used and the results obtained were compared with those obtained with the alkaline salt indicator. In each comparison with potable water

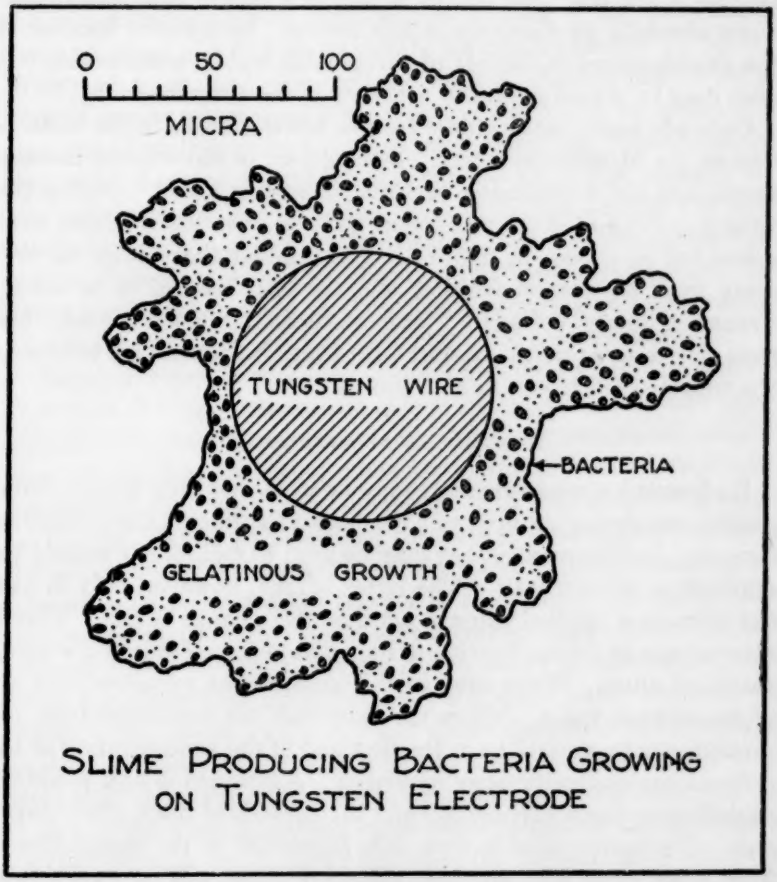

FIG. 5. Such bacteria may be of frequent occurrence in some public water supplies in the warmer months. They grow on all surfaces, and usually quite rapid. This destroys the sensitiveness of the electrodes and causes the voltage to drop; that is, the electrode drifts towards the acid sides. In such instances it is necessary to change the electrodes more often.

a difference of about 0.2 pH was obtained between the two indicator solutions. This experiment apparently confirms the explanation suggested above.

When accurate measurements are desired, the tungsten electrodes may be checked by standard buffer solutions without exposing the electrodes to the air. This is done by introducing the buffer at the bottom of the flow type cell by means of a rubber tube and funnel. Upon checking an electrode in this manner, by a buffer solution in the neighborhood of the pH of the potable water, considerable reliance may be placed upon the accuracy of the measurements.

Only one annoying electrode trouble has developed in the installation at the Montebello filters. During part of the warmer months, growths of slime producing bacteria sometimes occur. During this time a coating of slime was found to form over the tungsten wire, somewhat as shown in figure 5. This caused the voltage to drift away from the correct reading, and the drift seemed to be always toward a lower voltage. These biological growths usually last from one to two months, and at such times it is necessary to change the tungsten electrodes more frequently.

EXPERIENCE AT BALTIMORE

Hydrogen ion measurements may be used, not only to give information concerning the optimum conditions for precipitation, clarification, etc., but frequently they may be used to measure or control the application of chemicals. The latter is true, however, only in case the chemicals applied cause a considerable change in pH. This is always true in the application of lime and in some cases in the application of alum. When used in this manner the measurements are of the utmost value. When the chemicals are controlled from pH measurements, variations in the flow and of the concentration of the influent are evidently accommodated. Allowance is also made for variations in the concentration and the analysis of the applied chemicals. The latter point is especially important in the application of lime, since even with the best agitation there will be variation in concentration from the top to the bottom of a tank, or, if dry feed is used, in the density of the packing. If not used for actual control, the measurements can always be used as a check upon the application of chemicals and there are few plants in which such application is so precise that a check with an alarm device would not be valuable.

At the Montebello Filters the recorder is used to control the application of lime after filtration. A system of five signal lamps has been installed in the control room and this serves as an excellent remote indicator. A total of nine different positions on the scale can be

indicated. On account of the layout of the plant at Baltimore there is no way of obtaining a representative sample of the water soon after it is mixed with the lime. Consequently there is a time lag of twenty to forty-five minutes in the recorder readings. The operator consequently has to wait until the new opening of the valve has had time to affect the electrodes before he again changes its opening. With such a long and variable time lag it is probable that automatic control would prove none too successful and hence no attempt has been made at Baltimore to install such a control. Automatic control, with the new electrodes and calomel cells, has recently been proven successful in controlling the addition of lime in the Direct Oxidation method of Sewage Disposal.[15] This installation presented several difficult problems not met in water works practice and hence there would appear to be no difficulty in applying automatic control to water purification, provided the plant had a suitable layout.

Figure 4 shows two 24-hour records obtained at Baltimore. The record at the right represents a typical application of the lime as usually influenced by changes in flow, concentration etc., and that at the left was made while the operator was controlling the opening of the valve from the signal light indicator. On account of the time lag it is impossible to prevent fluctuations in the pH. However, the advantage gained in the latter control appears to exist primarily in *shortening the interval* of incorrect application. Thus, the record at the right shows that incorrect application frequently extended over periods of several hours, which is sufficiently long to have a considerable influence upon the clear water reservoir as a whole. The record at the left also shows periods of incorrect application, but these are shortened to about half an hour, and it is evident that these variations would be equalized in the reservoir.

One of the most important advantages gained by the introduction of the hydrogen ion recorder has been the psychological effect upon the operators. The type of laborer usually employed for operating chemical feed valves is frequently indifferent, unmechanical, and quite unautomatic. When no check can be made upon his work there is always a tendency for him to make no more motions than are absolutely necessary. Many plant managers would undoubtedly be very much surprised at hydrogen ion records which would show the non-uniformity of their chemical application of which they are now entirely in ignorance. But the importance of plant records are so

[15] Parker, *J. Am. Inst. Chem. Eng.*, Preprint, 1925.

obvious that this point needs no emphasis. The only thing which has been lacking has been the method of making such records and this need has now apparently been supplied by the apparatus described in this article.

SUMMARY

It is generally recognized that the hydrogen ion concentration is one of the most important factors in the proper purification of public water supplies. Apparatus is available whereby a continuous record of this important factor may be obtained with very little expert attention. This apparatus has been used for some time in controlling the addition of lime after filtration at the Montebello Filters. Records are given showing the more uniform chemical treatment obtained after the control was inaugurated. Automatic control appears feasible in plants having a suitable layout.

THE RELATION OF STORAGE WATER SUPPLY LAKES TO MALARIA[1]

By J. A. Le Prince[2]

With the rapid growth of our towns and cities the engineer is called upon to arrange for increased or new water supplies to meet future demands. Local conditions may make it advisable to increase the size of the existing storage water supply lakes or create new ones. The creation of such lakes may increase to a marked extent the prevalence of the malaria conveying mosquito (the Anopheles) in territory adjacent to the new or enlarged lake that may affect the malaria sick rate in families living within a mile of the flow line of the lake. There have been instances in recent years where most of the families have been so affected within two years after water was impounded. Such conditions often result in a number of law suits being brought against the parties who are responsible for creating the new lake or changing conditions in the enlarged one. Some of the legal action against the lake owners has been justifiable and some has not. There is always the possibility of the introduction of malaria into adjacent territory at the time the lake is formed. It is decidedly advisable to consider such matters in advance and cities building lakes should take precautions to protect themselves against unwarranted law suits. In some instances proper precautions are not taken because the engineers do not realize fully what conditions are favorable to the maximum production of malaria conveying mosquitoes.

As a general rule, conditions in a newly formed lake are most favorable to mosquito production during the first three years. In case we desired to produce a maximum of mosquitoes, a very good method would be to impound the water during June, July and August.

In the newly formed lake there is a considerable amount of floatage and debris that affords protection to the mosquito larvae as well as growth of algae (spirogyra) in which the mosquito larvae collect and where their natural enemies can not get at them.

[1] Presented before the North Carolina Section meeting, September 16, 1925.

[2] Sanitary Engineer, United States Public Health Service, Washington, D. C.

Of course, during the first or first and second year of the lake there is a marked absence of natural enemies of the mosquito larvae. That condition makes it desirable and often essential to supply an abundance of small mosquito destroying minnows. We find the Gambusia affinis, the pot bellied top minnow, is the best fish to use for this purpose in the South. It is advisable to use large quantities of these fish and to establish hatcheries for them near the site of the proposed lake, whenever possible several years before the lake is made. This question is covered in an article soon to be published in the 1924 proceedings of Malaria Field Workers, U. S. P. H. S., Washington, D. C. Under no circumstances should new lakes be stocked with bass or pike which destroy the Gambusia.

In general the lake which has an approximately constant level is more favorable to mosquito production than one with a fluctuating level. The more free the edge of the lake from floatage, aquatic growths and algae, the less favorable it becomes to Anopheles development. In most instances it is advantageous to keep the water 2 feet or more above maximum level during the non-mosquito months. This allows the wind and waves to strand the floatage on shore, kills vegetation, and permits the water body to be drawn down to a clean edge when the mosquito season starts. This clean edge affords very little or no protection to the larvae and fish get nearly all or all of them.

In clearing lakes of trees and brush it appears to be common practice to begin operations close to the dam and to lose interest as we get toward the upper end of the lake or of its arms. So far as mosquito elimination is concerned it would be much better to begin operations at the upper end of the lake and to be particularly careful to make a good job of clearing the upper end of each inlet. It is these inlets and particularly their upper ends that are most apt to produce mosquitoes and most certain to hatch law suits.

It is only that which pierces the water surface, such as brush, branches, rank vegetation, etc., or floats on it and either anchors floatage or gives protection to Anopheles larvae that we are interested in. Larvae do not collect around tree stumps unless they anchor floatage.

No matter how carefully a lake is cleared there is always a potential danger and periodical inspection is necessary during the first two or three years. Considerable floatage may be carried into the lake from the river or streams that feed into it, and such floatage

must not be allowed to collect in the lake and become a source of Anopheles at places within flight range of residences. It must be removed. Certain aquatic plants or their seed often get into the lake and such growths should be removed at once before they become numerous and costly to remove or control. Low places that become isolated ponds as the lake level lowers should be connected in advance to the lake by ditches so fish can enter them.

If in spite of all we do it is found that Anopheles production continues, then, if these mosquitoes can reach habitations, we must apply oil or other larvicide to the water surface, and in such instances it would be advisable to consult with the state board of health as to the most satisfactory and economical procedure.

Where any portion of a lake is producing Anopheles in fair numbers or in quantity, the adults may be found in shaded places in the daytime, in hollow stumps, small caves, under logs, etc., where they find sufficient shade from light and wind. We call such places Anopheles measuring stations.

The United States Public Health Service has been studying the relation of impounded waters to malaria outbreaks and malaria prevalence for a number of years. In Alabama, South Carolina, and Virginia the state health department regulations for the impounding of water are based on these studies.

In 1917, the Conference of State and Territorial Health Authorities discussed the advisability of having legislation enacted, which would permit the impounding of water on a large scale only after a license was obtained from state health authorities, which would prescribe certain conditions to minimize or prevent the danger of spread of malaria, and later the Public Health Service took this matter up again with the state health departments.

A brief outline of regulations is given below.

SUMMARY

1. It is not good engineering practice to endanger the health of rural population in our efforts to improve the health status of the urban population.

2. In impounded water projects the cost of removal of floatage, aquatic growth, clearing of inlets, inspection for collections of floatage, start of growths of cattail and other aquatic plants, and Anopheles elimination, should be included in the original plan and estimate.

3. In areas previously non-malarial, though Anopheles were pres-

ent, an epidemic can be created by the importation of malaria infected labor, and malaria prevalence can extend far beyond the flight range of Anopheles from the lake.

4. A high water level in the winter months will often reduce cost of removal of floatage and will reduce mosquito production.

5. Wherever possible Gambusia hatcheries should be established two summer seasons before water is impounded.

6. Provision should be made for constant periodical inspection of newly formed lakes. The inspector must know or learn habits of Anopheles larvae and be interested in their elimination. He should keep all floatage treated with oil or larvicide until it can be removed, and leave no places (where mosquito larvae are present) untreated.

7. The engineering division of our hydro-electric power companies have found the above to be good engineering practice and that its neglect is decidedly expensive procedure.

8. Bulletins and reprints on the relation of impounded water to malaria and relative to control procedure have been published by the United States Public Health Service, Washington, D. C. and may be had on request.

OUTLINE OF REGULATIONS FOR IMPOUNDED WATERS

1. Wherever impounded water projects are to be located under the provisions of this act in those parts of the United States in which malarial fevers exist, or malaria bearing mosquitoes are known to propagate, the following general measures shall be enforced for the protection of the public health:

(*a*) All laborers employed in the construction of the dam and the impounding of the water, shall be housed in properly screened houses and such steps taken by quinine administration and control of mosquito production in the vicinity of the camps as may be necessary to prevent the infection of malaria mosquitoes and the introduction of malaria into this locality.

(*b*) In the area to be occupied by the reservoir, its branches and indentations, all brush, trees, undergrowth, logs and similar objects, which if not removed would float on the surface of the impounded water and thus constitute conditions favorable to the production of malaria mosquitoes, shall be removed, burned or otherwise disposed of prior to the closing of the dam and impounding of the water. All trees or underbrush shall be cut sufficiently near to the surface of the ground to prevent their standing above the surface of the water at any and all stages of the water, and thus holding drift and floatage.

(*c*) The formation of log jams and the collection of drift and floatage in narrow valleys or indentations and along the banks of the reservoir where wave action is absent or weak, shall be prevented during the mosquito season.

(*d*) Insofar as practicable, the water level in the reservoir shall be fixed

so as to reduce to a minimum shallow, submerged areas on which aquatic plants will grow and reach the surface of the water.

(*e*) When practical the water level in the reservoir shall be held about three feet above normal high water level from December until the Anopheles breeding season in spring or early summer. After that time fluctuation is desirable.

On gently sloping banks or where stranding of floatage is practical, before the water is impounded the shore line shall be cleared of all undergrowth, brush, trees and logs, to facilitate the stranding of floatage, for a distance of about fifteen feet back from normal high water level.

During the first three years of the lake, its owners shall arrange for its constant inspection during the mosquito breeding season, and all sources of mosquito production shall be promptly eliminated or treated with larvicide.

(*f*) The reservoir shall be adequately stocked with top minnows which feed upon mosquito larvae and every effort shall be made to protect them against their enemies and secure their successful propagation.

(*g*) All separate pools and seepage places created during the construction of the dam or by the impounding of the water, whether adjacent to the reservoir or situated in the stream bed below the dam shall be filled, ditched, oiled, or stocked with top minnows (gambusia) in order to prevent mosquito production.

2. Whenever an impounded water project is to be located under the provisions of the Act aforesaid, the licensee shall obtain a permit from the State Board of Health and carry out such measures as the State Board of Health may determine to be necessary to prevent pollution of the drainage shed, or likely to cause or aggravate danger to the health of persons living near the lake.

3. The foregoing rules may be amended from time to time as necessary within the discretion of the State Board of Health.

REPORT OF STREAM GAGING COMMITTEE, NORTH CAROLINA SECTION, 1924–1925[1]

Your committee presented last year a report describing in detail the vital necessity of additional data on the flow of streams used or likely to be used for municipal water supplies. The experience of many municipalities in the state during the past year has served to give a strong emphasis to the need for such information. Had it been available, there is little doubt that some of our cities would not be facing the present acute situation relative to their water supply today. The committee recommended, and the Section endorsed the report, that the state appropriate at least $40,000 per year for coöperation between the State Department of Conservation and the United States Geological Survey in stream flow and allied hydrological investigations. The Legislature appropriated a little over $8000.

What has been the result? A critical period has occurred in the flow of many of our streams due to the extreme drought conditions. It became imperative that as many measurements as possible be made of this crucial flow. During the month of July, 53 measurements were made, and during the month of August, 65 such measurements of extreme low flows were made on streams all over the state, from Murphy to Roanoke Rapids. As a result travel funds have been depleted to such an extent that the regular measurements necessary to the rating of the existing gaging stations will have to be seriously curtailed, and if floods occur it will be impossible to make trips to measure them during the present fiscal year. Absolutely no additional gaging stations can be established, in spite of the request for them on the part of municipalities and others. Mr. J. H. Morgan, experienced office engineer, has had to be released from the Asheville office, due to no funds with which to continue his salary. As a result the compilation of stream flow data is considerably delayed and current information cannot be furnished to municipalities with the requisite promptness.

At the time of the committee's report last year there were in opera-

[1] Presented before the North Carolina Section meeting, September 16, 1925.

tion in the state 34 regular gaging stations of which four only were equipped with recording apparatus. At present there are 53 regular stations, of which 13 are equipped with recorders. This indicates, in the opinion of the committee, a most praiseworthy accomplishment of the stream gaging authorities acting under severe handicaps. As indicated above, the limit to additional stations has been reached because of lack of funds.

The committee desires to commend the City of Durham for its action in appropriating $2000 for extensive stream gaging, rainfall and evaporation studies to be carried on by the State Department of Conservation and the United States Geological Survey. It appears likely that the City of Greensboro will undertake a similar investigation. It should be pointed out, however, that the appropriations from these cities are for materials and labor only. The cost of design, supervision, operation, and compilation of records are carried by the state. Lack of personnel and travel funds has prevented the establishment of these stations for several months after the local coöperation has been secured. No more such joint investigations can be undertaken, due to lack of funds to carry the overhead on the part of state authorities.

The committee recommends that there be appointed a Standing Committee on Water Resources and Forestation, that this committee begin to function at once by getting in touch with water works superintendents, engineers, city officials, and others to impress upon them the importance of having the next Legislature carry out in principle the recommendations of this committee adopted by the Section last year.

The committee further recommends that the Section endorse the bill prepared by American Engineering Council for introduction into Congress providing for a uniform and increased investigation of the water resources of the country.

Respectfully submitted,

D. M. WILLIAMS,
M'KEAN MAFFITT,
SHERWOOD BROCKWELL, *Chairman.*

FOAMING IN COAGULATING BASINS AND AIR BOUND FILTERS[1]

GEORGE D. NORCOM:[2] I have had foaming, but I always felt very good whenever I saw it, because I always found, when the chemicals were re-acting very well, it was a usual thing for foam to begin to form in the mixing chamber, that is, just great masses of dark brown colored foam would climb up out of the top of the mixing chamber. In fact, it might be carried out to the sedimentation basin. We find when the wind is blowing rapidly it will shower the foam like snowflakes all over the place. I am not prepared to say definitely what the cause of it is. My own hypothesis is that under certain conditions of temperature, surface tension and other physical phenomena, the carbon dioxide formed by the reactions of alum and natural alkalinity rises through the surface scum and causes the formation of the bubbles.

The reason I say that I think it is a good sign is that usually when you get that condition your chemicals are reacting very thoroughly; there is little free alum left in your filtered water. In other words, the reaction is complete, the alum is being completely precipitated, which is the thing you are after.

Since the treatment of water is a chemical process, and this foam is a natural by-product, as I think it is, even though it does look a little bad to visitors, if it is explained to them as being nothing at all except harmless foam and the natural resultant of the chemical treatment, why should they find any cause to become alarmed or consider it as disfiguring as the natural brown stains you frequently get around your filters. No matter how hard you scrub or wash, you will have them. We do not like the looks of those and we have men scrub them off with steel brushes and paint the surface with cement to make it look white. Still, it is unsightly, although it is merely the colored matter and the iron in the water precipitating out which causes that discoloration. I think the same thing can be applied to the foam.

[1] Topical discussion before the second annual conference, Filter Plant Operators, North Carolina Section, September 14, 1925.

[2] Superintendent of Filtration, Wilmington, N. C.

As to air bound filters, we have also had some trouble. You all know the phenomenon. The filters are apparently working beautifully. Suddenly you discover you are not delivering any water. Your loss of head is running up high, and on cutting it off you get a great rush of air from the interior of the filter, breaking up the surface. If you were not going to wash it, anyway, you would have to wash it then. Some say that is the natural air dissolved in the water which is liberated under the uneven pressures which vary from the atmospheric pressure to those developed in the lower part of the filter. Others claim it is due to the dissolved oxygen in the water which may be released by reduction in the pressure.

I have never analyzed any of that air that comes up out of the filters and I am not prepared to say whether it is natural air or whether it is largely oxygen. But as far as any remedy for the thing is concerned, you can try cracking the filter, that is, just cracking it and putting it back into service again, which will get rid of the air. It generally produces a mighty bad effluent, and I can not use that system on my filters. If they get air bound, I crack them, but it is a hopeless proposition for them ever to come clear again.

About the only other thing you can do, that I know of, is to wash them. But, fortunately, I have never had the condition persist any great length of time. That is, we might have some trouble with a few filters for a short period of time, but, as a rule, the air binding is not serious enough, in my case, to make it a bad situation.

A. O. TRUE:[3] With reference to foam, I think foam, as we ordinarily see it in a filter plant, is merely a mixture of gas and suspended matter, probably finely divided clay, which gives it this brown color, and coagulant, which is a slimy material. The combination of those three materials forms what appears to be foam.

There might be several sources of the gas. We can understand where the coagulant and where the clay comes from, but there may be several sources of the gas. One source of the gas Mr. Norcom already mentioned as the natural carbon dioxide which is liberated by the chemical reaction when aluminum sulphate is introduced into your alkaline waters.

A second source of gas which would form foam could be from the condition of your water. Water has a saturation point for air. It

[3] Sanitary Engineer, Proximity Manufacturing Co., Greensboro, N. C.

will dissolve a certain amount of air, under different conditions of temperature and pressure, and it is a common thing to observe water when those conditions are over-balanced. For a given pressure or a given temperature, or a combination of the two, water will dissolve a certain amount of air. If those balanced conditions are overthrown, air precipitates out in very fine particles. These finely divided bubbles give it a milky appearance. So that temperature would change, if the water had been under pressure coming from a reservoir and suddenly that pressure was released; or if a change of temperature came along, it is readily understood that the air might separate out, and becoming mixed with the finely divided matter would carry to the top.

A third source of the gas might be decomposition. We spoke of it this morning as decomposition of the sludge which would give off methane gas or carbon dioxide, or both.

I agree with Mr. Norcom that, while foam is rather an objectionable thing to the average layman, it does not really amount to anything. It does not interfere with any processes, apparently, and if it gets washed away from the sides of the filter and the various surfaces it collects on, I can not see that it is very objectionable.

GEORGE F. CATLETT:[4] There are two conspicuous facts about foam. One is that it is more prevalent with the colored water. It is present in practically all colored waters, and persists longer and is worse, although I have seen it in connection with some waters that had no color in them.

You will also notice it in hot weather more than in winter. The foam, itself, is coagulant. I have taken some of it and examined it and found it to be coagulant.

As I said this morning, the floc that you get with the colored water is a good deal more feathery and lighter than you get with clear water. It is almost impossible to get that fine, pin-head floc on the colored water. If you get floc at all, it comes in these large, light, feathery pieces. With that foam, of course, there is always an ebullition of air. I think the reason the colored waters get it more than the others is due to the fact that the coagulant is light and the bubbling of the air set free, which you will always find with the foam, is better able to raise it than the heavier clay floc.

The worse case of foaming that I ever saw was on a water that

[4] Sanitary Engineer, State Board of Health, Raleigh, N. C.

was not colored. It was a basin that was heavily baffled. It was baffled so heavily that it was almost a mixing chamber, and on ordinary conditions the old floc would keep in suspension, would keep rising up and gradually the smaller pieces would conglomerate so that it would be in large chunks.

The question of foaming is a question closely allied to air bound filters. Foaming is due pretty much to that, outside of the nature of the floc.

In this plant that I was speaking of, we were called by the superintendent. He said his filters were getting clogged up and he only got a half hour's run. At the end of a half hour's run his rate would fall off and in less than an hour he could hardly get any water through the filters. Just before that we had a similar experience where the condition was due to cyclops and microorganisms in the water. I thought that was also the case in this instance. It was in the same locality.

As soon as I shut the filter off, the air boiled out of the filter. On examining the bed, it was found to be perfectly clean, and microorganisms had nothing to do with it.

I went out to the coagulating basin. It was boiling like a potato on a fire. It was carrying coagulant up and foaming. The foaming was rising up and going over the basin. They had men with shovels out there, and the whole ground around was covered with what they had shoveled off. It was about the most extreme case of that kind I ever saw. At the same time, the plant was getting a rather heavy, feathery floc. It was clay water, and ordinarily they can get a fine, heavy floc, but they were getting this feathery floc.

The foaming is due, therefore, to the ebullition of air with very light coagulant. With entrained air it forms a foam on top of the basin. It does no harm. I know no way to prevent it, except to shovel it off.

In regard to the air bound filters, first I thought it was because of the hot weather. I thought there was some vegetable decomposition there and probably carbon dioxide. The carbon dioxide was down to about 6. At that time the thing disappeared in a short while, with a rain, and we did not get a chance to examine the gases coming off. But later on at that same plant, when we had a similar trouble, although not such an extreme case, we did examine it and found that it was air that contained oxygen in just about the same proportion as ordinary air.

Mr. Lasker, of the Raleigh plant, made some tests a short time ago to determine the total dissolved oxygen in the water before and after it went through the filter, He had, in his basin, where it was bubbling, a super-saturation of about 110 per cent. When it reached the filters, I think it dropped to about 85 per cent. It came through the filters with about 76 per cent, approximately. We made a determination of the gas that was coming off, and found the proportion of one to four oxygen and nitrogen was about right, as existed in all waters. Carbon dioxide had not increased.

Another thing I have noticed about effusion of gas is that it is much more prevalent in plants where they have a large and very shallow reservoir of stored water. One of the worst places where I have observed that is at Henderson, where the reservoir covers a wide area, but is very shallow. The water is exposed to the action of the sun, and on the hottest days the effusion of air is worst. Following a rain, or where the temperature changes, there is an immediate cessation of gas ebullition.

In connection with Henderson's reservoir there is some spring water feeding the reservoir that is usually at a very low temperature, and evidently contains fairly high oxygen content.

A. O. TRUE:[3] I would like to ask Mr. Catlett, in that case he cited of extreme foaming, was that a permanent or just a temporary condition?

GEORGE F. CATLETT:[4] It only lasted a few days and then disappeared, following a heavy rain.

A. O. TRUE:[4] During the warm weather?

GEORGE F. CATLETT:[3] Yes.

MR. MEREDITH: I have considered whether that condition might not be brought about by fertilizers put on the water-shed. It seems to me that more of our water-sheds are being cultivated every year. It is a fact that we did not get that trouble when we first commenced, but afterwards it developed and has been with us ever since. I just wondered if it might not be from certain fertilizers.

E. G. MCCONELL:[5] I would like to ask Mr. Catlett whether or not,

[5] Superintendent of Filtration, Water Works, Charlotte, N. C.

during this period of excessive basin foaming, there was any indication of air binding of the filters.

GEORGE F. CATLETT:[3] That was the time I was called upon to investigate the trouble with the air bound filters, and found the basin foaming.

E. G. MCCONNELL:[5] At Charlotte, we have a water that is easily treated. We were operating the old wooden tub filter and we never had any trouble with air binding in those filters. The first year we have been operating at our new station, which has the under-drain system, under those concrete units, we have experienced trouble. However, I do not think that there can be any definite conclusion as to relation drawn there, because of the fact that, at the same time, our raw water was changed from the open river into a large reservoir, caused by the building of a hydro-electric plant just below us, and the location of our intake just adjacent to this dam.

At any rate, during the winter months, when the turbidity ranges from 50 to 400, we get filter runs as high as a week, without ever getting a sufficient loss of head to wash the filters.

As soon as this dry season started, this spring, and our turbidity began to drop below 50 or 40, we began to experience this trouble. Our filters would air-bind in six hours. As Mr. Norcom suggested, we first cracked those filters to get rid of the air, and placed them back in service. But that certainly is not a satisfactory means of handling it, so we immediately changed our procedure to simply washing the filter, even if it did take more wash water. It is better, in the long run, to wash it out. At certain times those filters were so air bound that when we merely shut off the filter our air would come up without even draining down. In other words, the air would rush up before we even let the filter down. It would vary. Of course, some filters would begin to bubble up before we could let it down. In each case, however, just as soon as we reversed the flow of water, we of course had a rush of air.

We have installed now an apparatus for making dissolved oxygen tests. We are going to see if we can find out anything along that line. We have made a few tests, but not enough from which to draw any conclusions.

I also made another little experiment there. Our under-drains are so constructed that the effluent therefrom is through a cross which connects to the underdrain system, through a concrete wall about

eight or ten inches in thickness. On top of this cross it was level, or a little bit higher than the top of the under-drain system. I naturally concluded, therefore, if there was any air in the under-drain system itself, I could get some by tapping this cross, because it was as high as, if not a little higher than, any part of the under-drain system. But when I tapped it I could not get any air, regardless of how highly air bound the filter was. I concluded, therefore that this air must be in the sand bed itself, and not in the under-drain system.

A. O. TRUE:[4] I would like to ask what rate your filters were running at the time you had this air trouble?

E. G. MCCONNELL:[5] Normal rate.

A. O. TRUE:[4] Some years ago, George W. Fuller pointed out, in connection with the air binding of filters, that the plane, as he called it, of maximum resistance in a filter was near the sand surface, and if the air particles were located or rose in that filter to a point at or near the sand surface, very serious air binding would take place; but if those air bubbles were located at a lower plane, they would not be so serious—it would not cause such a loss of head. He pointed out also in a filter running at a rather rapid rate, say a normal rate, that air bubbles would be carried to the lower strata of sand and might even be carried through the under-drainage system and pass out with the effluent. Probably often that would be a continuous process. Air bubbles, as fast as they were being formed, instead of binding the filter, would be carried out in the effluent. Whereas, if the rate of filtration had been much lower, the bubbles would have risen in the sand bed where they would cause the resistance which we get, probably, when the filter is air bound.

E. G. MCCONNELL:[5] I am very much handicapped at Charlotte in not having any rate of flow gauges on our filters. Of course, we have a means there of regulating the flow of the filter by an orifice. But since that changes during twenty-four hours, according to the amount of water we have in our clear water basin, it causes the head to vary on the controller. The rate of flow changes and we have no rate control.

Now, I have noticed that, over a holiday or a Sunday, we do not

have as much trouble with air binding. The filters will run for a longer period than when they are running normally through the week, which shows that the more water you pass through the filter, the more air you are going to liberate. I am pretty sure that it is either dissolved oxygen or air that is liberated in the sand bed itself; that is, it is entrapped in the sand bed.

L. L. HEDGEPETH:[6] Our pumping plant is located on the creek. We take water from the creek direct. When the creek is low, and the intake pipe is not full, I get air binding in the filters. When the creek is high, I do not get it.

E. G. MCCONNELL:[5] The head of water coming into our plant is practically uniform, because we store it in a basin which will hold about a seven days' supply. Even after it comes from this hydro-electric dam, it is stored again for about a week before it comes to our plant. The level in this storage basin is kept uniform, of course, within reasonable limits. We take it by gravity from this basin, by a twenty-four inch cast iron line.

So I think that in our case it evidently is the nature of the water itself. The dissolved oxygen or the entrainment of air must vary somewhere beyond our plant.

W. H. WEIR:[7] Mr. Baylis of Baltimore had some experience on filters, and he decided to go back further and look for the trouble. He found a peculiar situation at his intake. Since the pumps churned the water up in very small bubbles, he carried out a series of experiments to determine the amount of air which could be held in small and in large bubbles. Mr. Baylis has since published an article in Industrial and Engineering Chemistry. He said his trouble was entirely from the intake. When he corrected that, he got rid of almost all of his troubles.

E. G. MCCONNELL:[5] Our conditions are so uniform at Charlotte that we have the same pumps going all the time, and supposedly they are packed about the same. I do not think there is any question, if the packing glands are not correct, that you can have a lot of waste

[6] Thomasville, N. C.

[7] Assistant Engineer, State Board of Health, Raleigh, N. C.

while your pump is down and you will pull in air while it is running. Our intake, being submerged several feet, should not cause any churning. We do, however, discharge into this storage basin through a series of six-inch nozzles turned up, and it merely overflows through those nozzles. But that goes on all the time. All the water is discharged that way. So I am inclined to believe that our trouble is probably before it even gets to our river intake.

A. O. TRUE:[4] There is another source of air which I do not think has been mentioned, and that is in leaky filter connections. When the filter is operating under a negative head, you have a less than atmospheric pressure in your filter connection and in your controllers, and if there is any leak, or leaks, in those, air will enter at that point. It is reasonable to suppose that that will continue on and get into the filter.

T. C. PATTERSON:[3] When the construction engineer of the Norwood Company installed our filters with a three-quarter galvanized pipe from a short tube on a loss of head gauge, he brought it through the wall with a sand strainer on it. It was about 4 inches down in under the sand, and before we got to operating there Mr. Weir came down. We had trouble with No. 2 filter. It was air bound and when we cracked the wash line, it bubbled up. Thompson came back and our walls were leaking badly. He said he thought it was the walls, but I did not see how that could be because the pressure was out. In working around this loss of head gauge, I discovered that the short tube was sucking air and you could hear it gurgling and bubbling. I told Thompson about it. He did not think that was it. But Mr. Weir had gone away and left instructions when he came back to take that three-quarter pipe out of the sand bed and put the strainer on behind the rear wall. Immediately after we did that we had no more trouble with that filter. This pipe was about an inch or two inches deeper in the sand bed on No. 2 filter than on No. 1. I think that is where that air came from. The filter was sucking it from the loss of head tube.

E. G. MCCONNELL:[5] Mr. Patterson, you are located on the same water supply as we are, a few miles below us. Do I understand you have had no further air trouble after you took out this tube?

[3] Superintendent, Water Works, Mt. Holly, N. C.

T. C. PATTERSON:[8] No, I have had no further trouble after taking it out.

J. H. SUGGS:[9] I have had some trouble once or twice, and I found that all my trouble was in the controller. The air lands on your controller and accumulates and backs up on your filters in some way. I stopped the leaks around the controller and I have no more trouble.

E. S. MCCONNELL:[5] In view of the fact that at Charlotte we got along with our weekly run one season of the year, and at another season of the year we could have a six hours' run, I am still inclined to believe it is something else besides leaks around our filters.

I am making dissolved oxygen tests, as routine tests for next year, and hope to have something definite along that line for the next meeting.

T. C. PATTERSON:[8] I am only about three or four miles below you. Wouldn't I have about the same trouble you have, if it is caused by oxygen?

E. G. MCCONNELL:[5] You ought to have. Maybe your filters are different from mine.

S. F. CATLETT:[3] There is a difference. Your water is taken right directly from the river.

E. G. MCCONNELL:[5] It is taken from below this dam.

S. F. CATLETT:[3] You have a storage reservoir in between.

Talking about rate controllers, they are supposed to have a seal on them. We have found on several occasions that the seal was incomplete. If that seal is incomplete, it will certainly take air. That is a common cause of air trouble with the controller.

[9] Water Works, Durham, N. C.

STERILIZATION OF WATER MAINS AFTER LAYING[1]

By C. W. Absher[2]

It is well known that the pollution of new water mains is almost unavoidable as the ditches are sometimes dug through mud and all kinds of disagreeable filth. Even in dry ditches, however, there is always a chance of contamination from the soil that would at least result in a good many cases of diarrhoea. No one knows what disease the workmen themselves may have or what kind of an epidemic they might start from handling the pipe.

Therefore in order to protect the consumers from these possibilities, why not take advantage of the well known sterilizing properties of liquid chlorine? The dosage can readily be checked by the orthotoluidin test just as it is at the purification plant. This paper however need not go into that part of it, but will try to suggest some new idea for the appliance of the chlorine.

It seems best that a considerable time should elapse after the chlorine is applied to the new main before it is put in service. This gives more safety to the procedure and allows more time for the mechanical tests of the main. The simplest way to gain both these ends is to test the water main after each day's laying by means of a detachable test plug with a rubber gasket that can be clamped in the bell and or, if necessary, on the spigot end of the pipe, These plugs have a threaded orifice in which a short nipple and stopcock can be inserted to rid the main of air. The tank of chlorine can be connected to the main just beyond the point where the new work started by means of an ordinary corporation cock. Then the water and chlorine could be admitted simultaneously, leaving the chlorine on until the orthotoluidin test shows complete sterilization. The water for the test being taken from the orifice in the plug.

The passage of the chlorine through the corporation cock would probably ruin it, if it is not cleaned up soon afterward.

[1] Presented before the North Carolina Section meeting, September 15, 1925.

[2] Superintendent, Water Purification, City Water and Light Department Mt. Airy, N. C.

DISCUSSION

W. E. VEST:[3] My experience has been that the sterilization of water mains after laying did not have as much attention long ago as it probably should have had. It is not the custom, in the city from which I come, to go to any great expense or any great time for sterilization, though the mains are very thoroughly washed by flushing for quite a while.

I will be glad to hear from members all over the house as to their practice, in their cities, and also the necessity for sterilization of new mains.

C. S. LOGAN:[4] I think that is very essential, although they do not do it out at our place. I had a break between my filter plant and the reservoir in town, and we had to repair it at night right in the swamp, and I know we got infection through that. If we had an arrangement there to sterilize, that would not have happened.

H. A. LILLY:[5] We had a little experience last spring along that line. We put in a new water main over a distance of about a mile and a half, and previous to putting that main into service we flushed and put in clear water for something like an hour and a half. We did not disinfect, and the next day we found bacteria in our mains, which necessitated going through our clear water storage basin and dumping the disinfectant in.

M'KEAN MAFFITT:[6] I am glad this subject has come up. I have been laying water mains for twenty-five years, and I have been in a rut like all the rest of them. I have never sterilized the main. But I will never lay another one without sterilizing it. I will give two illustrations here as to why they should be sterilized.

We were laying a 6-inch main in Florence, S. C. One night, as we knocked off, one of the negro laborers took off his work-shoes and stuck them in the end of the 6-inch pipe. We did not know the shoes were in the main and the next morning started in the usual manner laying the pipe. We got to the end. We started to flush out the main

[3] Superintendent, Water Works, Charlotte, N. C.
[4] Superintendent, Water Works, Waynesville, N. C.
[5] Tallassee Power Co., Badin, N. C.
[6] Superintendent of Water and City Engineer, Wilmington, N. C.

in the usual manner. We were getting a fairly good representative flow when suddenly, with somewhat of a crash, the flow ceased. Two joints were blown out. Immediately the flow started again and ran for probably a second, and then stopped the second time with another crash. At the second crash, the water hammer broke the hydrant in two.

The foreman in immediate charge of the work, at the first stoppage of the water, went to the valves at the starting point and started to close them, so we did not have very much trouble with the line with leakage. We found the pair of shoes of the negro laborer that had dammed the water completely and caused the water hammer to blow out the two joints and the second time to break the hydrant in two and crack the flange at the base.

If a pair of laborer's shows can get into the water main while you are laying it, how many bacteria may be on those shoes or get into that main from other sources.

Another instance happened in the same town. A nice, white, large leghorn hen escaped from the neighborhood poultry yard and the children were chasing that hen through the street, trying to catch it, and ran it into the ditch and she ran into the end of the 6-inch pipe. We happened to know that the hen went into the pipe, so we went down the line and opened the 6-inch valve and blew the lady out.

I asked the chemist on the building of the plant to express his opinion—I had great confidence in that gentleman's ability as a bacteriologist and I wanted him to express his opinion on the danger of bacterial infection from newly laid water mains that are not thoroughly sterilized.

GEORGE D. NORCOM:[7] As Mr. Maffitt has already told you, we were not in the habit of sterilizing any new mains, and at the first flush the thought occurs as to how the thing could be done most easily. I do believe that they should be sterilized. The illustrations already given are sufficient to emphasize the need of that. And then, of course, the pipe, as it comes to us, is likely to be in bad condition, contaminated one way or another, to say nothing of what might get into it during the process of laying. So that it seems to me it should be sterilized.

I had intended to say something more, or make some remarks,

[7] Sanitary Engineer, Board of Health, Wilmington, N. C.

after the paper on "Freshly prepared hypochlorite solution," by Mr. Lilly, because it may not be exactly practical for everybody to have a portable chlorine machine that could be taken to the city of the newly laid mains for the application of chlorine.

In France, they use a solution of sodium hypochlorite and since the war that material has become available in this country. It is rather an alkaline solution of sodium hypochlorite and it is sold in this country under the name of D. K. Solution and various other trade names, and has been used very largely in the dairy industry in sterilizing bottles. It is a very efficacious substance and can be carried around in five gallon bottles. It runs from about three to four per cent available chlorine.

I presume most of you are familiar with that material. It occurs to me that, in the event that one did not have a portable chlorinator, it would be possible to take a sufficient quantity of this material to the point where the new mains were being laid and apply it in the main with sufficient water to carry it through, and in that way effect sterilization. Your orthotoluidin test would be just as valuable with that material as it would with liquid chlorine. It might be that for a small job you could get it much more cheaply than purchasing a chlorinator. That material does not cost very much to make, but because of the fact that it is sold under a trade name it is very much more expensive than liquid chlorine. That is a condition that possibly could be remedied by concerted action on the part of the waterworks men. In other words, if it merely could be used around the water works plants and in the mains, and one thing and another, it might be possible to bring enough pressure to bear on the manufacturers to get it at a reasonable price. It does not have to be chemically pure. The main thing we want in it is chlorine.

There are a number of other uses to which that material can be put, that I might just mention in a general way. It so happened that I was made a present of some twenty-five or thirty gallons of the solution, and I find it a very nice thing to have around the waterworks plant because, in case of any little local infection of any of your units it is very easy to treat that particular unit or piece of pipe, or whatever it may be, basin or reservoir, with chlorine in this manner, where the use of a chlorinator would either mean the purchase of new equipment or the transferring of some stationary equipment to various points around the waterworks plant or away from the waterworks plant, which is not a practicable thing to do.

We had some filters that were infected with organisms which were giving us rather too high a bacterial count, and we used some of this material in the filter for the sterilization of the filter proper, that is, the sand and underdrains. It can be applied for that purpose. It is already strongly alkaline and can be used in conjunction with caustic soda for the removal of accumulated alum residue, which I presume you all have on your filters from time to time. In the case of an infected filter, the entire filter can very readily be sterilized by a sufficient quantity of this stuff and drawing it down through the filtered waste valve until your whole filter is thoroughly impregnated with this solution which will result in the sterilization, and if used in conjunction with caustic soda will mean the removal of accumulated alum sludge from the upper layers of the sand and the surface of the sand.

I just offer that as a suggestion, more particularly in connection with the sterilization of small water mains. I presume on a very large job, where a great deal of pipe is being made, it might pay to have a portable chlorinator. It certainly would be a much better way to effect sterilization if you could afford to buy the chlorinator. However, this solution will accomplish the same result on a small scale.

GEORGE F. CATLETT:[8] Quite recently Asheville had occasion to sterilize some mains and some filters. We have not had any difficulty doing it simply with chlorine. We started an emergency filter plant up on the North Fork shed at Asheville, and it was very important, for various reasons, that we should get no B. coli in the laboratory test. Of course, the new mains will show B. coli and it really has not much significance. The objection to it is that it obscures the laboratory findings and entirely vitiates the value of the laboratory test.

We had to be careful, therefore, in starting up these emergency plants, to see that the mains and the pump wells and boxes should be thoroughly sterilized. They accomplished that on this North Fork installation by running a six-inch line over to the gravity main which comes down from the North Fork shed. We had that sterilized. We started the filters up and got water into the pump boxes, using a steam-fire pump. We started that pump going through the six-

[8] Sanitary Engineer, State Board of Health, Raleigh, N. C.

inch line and let the water go out through a ball valve. We simply took the tank of chlorine, put a piece of rubber tubing on it and put it down into the pump well close to the suction, and ran that. We got a very strong orthotoluidin reaction there. Then we had a man who continued running that chlorine just from the tank, until he smelled chlorine at the blow off. We then shut the pump down and let that water stay in the main for ten minutes and then started up in a normal way.

In the case of the Asheville Lake installation, they had an improvised filter. It had just been constructed of wood and filled up with stone and sand. There is no question, but that you have got a B. coli reaction from that filter bed. It had no significance except that it would obscure the laboratory control of the water and would give positive tests in the mains entirely from that cause, and we would not have known whether other causes entered into it at all. We used the same method there. We took the tank of chlorine up and the rubber hose, and cracked the valve and let it drop into the rubber tube all over the filter bed until we got a very strong orthotoluidin reaction. Then we sterilized the pump well and also the pipe line in the same way. It seems to me that in all filter plants, all filter supplies in the State that have chlorine available, a simple tank of liquid chlorine can be utilized in every case to sterilize the main or any part of the plant. Of course, in a deep well plant where they are not using chlorine sterilization, it is necessary to provide other means. But it seems to me that the tank of liquid chlorine can be utilized for sterilizing mains and be also used as Mr. Norcom described in the chlorine solution. We have done that at Asheville very successfully. We had no difficulty in putting it in, and the results were perfect. We got sterile plates.

BURT B. HODGMAN:[9] Recently, in Newark, a 20-inch main was laid, the ditch was flooded overnight and they got two or three inches of clay mud in the pipe. They sterilized the pipe after they had finished the laying, and flushed it, but they still got B. coli after a test two or three weeks later.

MR. LEGREE: I just had an experience along this same line in a little town in South Carolina. The water showed up contaminated.

[9] Civil Engineer, New York, N. Y.

I thoroughly investigated the water supply. It was a deep well. We tested the water at the pump, in the reservoir and in the standpipe. We found good water. We tested it down-town at different points and found the water contaminated. I filled up the tank and drained the reservoir, left the tank full, thoroughly cleaned out the reservoir, put in a solution of hypochlorite and filled up the reservoir. Then I drained the main and the tank and filled the system with this water. We found in the main, in some cases, mud, etc. We treated this water for two days and the bacterial tests showed up all right. Since then they have had no trouble at all. Unquestionably, the contamination was due to laying the new water main and not taking the necessary precautions after the system was built to disinfect it.

GEORGE D. NORCOM:[7] It has been my opinion that you cannot hope for any penetration into several inches of mud that may be at the bottom of the pipe. I do not think that the chlorine could possibly penetrate that deeply so as to do away with all chances of contamination. It would seem, in Mr. Hodgman's case, as if some other method of cleaning that main would have to be resorted to.

GEORGE F. CATLETT:[8] In connection with the sterilization of the main, the case I just cited was one in which we had complete supervision, and the North Fork shed was far enough away so that we had no fear of putting in a little bit excess chlorine—we felt it would disappear after it passed through that long line. In the second case we blew off the chlorine.

Some time ago we had a case of new filter plant, and as usual, we increased the chlorine, sterilized the main—and nothing was said about it to the public. The Coca-Cola Bottling Works in town bottled a lot of goods, using this heavily chlorinated water, and sold it to the surrounding towns, and they came back very indignant and were going to sue the town. They said that they not only had to destroy those goods, but they had had their trade ruined and it put them at a disadvantage with their competitors.

I think there is a lesson we can get from that incident, that it is important to handle sterilization intelligently. It you can not blow the water off, waste the water that you use for sterilization. The people should be advised of it before it is done.

In one case the people were advised, and not only that, but they did not want the people to drink the water at all, but to boil it. And

one of the objects in putting the chlorine in was to develop a taste so objectionable that they would not drink it.

In another case, they had a pollution and they decided to sterilize their mains. So they used the newspapers and warned the people that at a certain time they would put this chlorine in there and it would have a bad taste and it would be entirely harmless, though slightly disagreeable. That went by without any difficulty.

But I think it is important, when you adopt sterilization methods to provide either for wasting that water or else advising the people that it must be done, and give them the entire facts about it.

J. E. GIBSON:[10] Before you close the discussion I would like to ask if any of these men have chlorinated new mains and have had any phenol taste, due to this sterilization.

GEORGE F. CATLETT:[8] We usually have a slight phenol taste in the mains, anyway, although we have no scientific facts and figures before and after. But the general observation is that there is probably a little of that taste.

[10] Manager and Engineer, Water Department, Charleston, S. C.

STERILIZATION WITH FRESHLY PREPARED HYPOCHLORITE[1]

By H. A. Lilly[2]

The attached sketch shows a device used for combining chlorine with an alkali, and feeding the resulting hypochlorite into water for sterilization purposes. The chlorine passes out of the cylinder through a copper tube, enters the bottom of the glass chlorinating chamber through a glass tube, and bubbles through the solution of alkali as the alkali passes in at the top of the chamber and out at the bottom. When the alkali is in the form of a carbonate, hypochlorite is formed in accordance with reaction 1.

(1) $$R_2CO_3 + Cl_2 = RCl + ROCl + CO_2$$

When an alkaline hydrate is substituted for the carbonate, the chlorine combines as shown in reaction 2.

(2) $$2ROH + Cl_2 = RCl + ROCl + H_2O$$

In either case the fresh hypochlorite solution passes out of the chlorinating chamber into the filter effluent and decomposes in accordance with reaction 3. The nascent oxygen destroys the bacterial life in the water.

(3) $$ROCl = RCl + O$$

The above method of sterilization has been in use at the Badin filter plant since May 28, 1925. When the filters are started the needle-valve is opened wide enough to give a slight excess dosage of chlorine, the ortho-tolidine test is applied and the dosage cut down to 0.3 part per million which, in the case of Badin water, gives a satisfactory sterilization.

The number of pounds of chlorine added per twenty-four hours is

[1] Presented before the North Carolina Section meeting, September 15, 1925.

[2] Chemist, Tallassee Power Co., Badin, N. C.

determined by weighing the cylinder at the beginning and the end of the day.

The quantity of alkali is governed by adjusting the valve on the effluent pipe of the chlorinating chamber. Enough alkali is added to raise the pH of the filter effluent from 6.4 to 7.0.

The normal variation of bacteria per cubic centimeter in the filter effluent, previous to the addition of hypochlorite, is from 5 to 50; after disinfection it is from 0 to 2. Daily tests on 10 cc. portions of

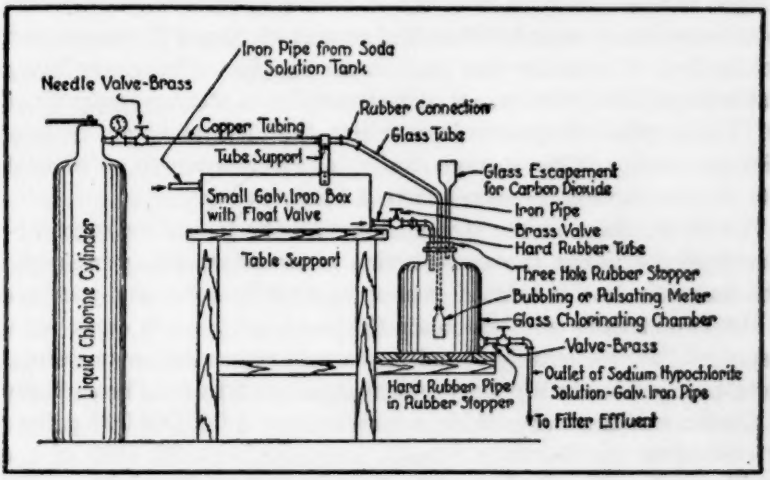

FIG. 1

water treated by the above outlined process have failed to reveal the presence of colon bacteria since the process was put into use on May 28, 1925.

The entire equipment including scales cost approximately $50.00. The equipment is easy to assemble, install, and operate. Any broken parts may be replaced at small expense, and no expert has to be called for repair work. In closing I would like to state that I think this process of sterilization is most economical and efficient.

EFFECT OF IMPOUNDING RESERVOIR ON WATER AT GREENSBORO, N. C.[1]

By C. W. Smedberg[2]

Prior to the construction of the impounding reservoir at Greensboro, dependence was placed on the combined flow of Horsepen and Reedy Fork Creeks for the city water supply. The water being drawn direct from the stream and pumped to a storage reservoir of 20,000,000 gallons capacity from which the filtration plant is supplied by gravity The storage available in this reservoir at present rate of consumption is equivalent to a 5 days supply.

The fluctuations in the stream flow and the mounting consumption made pertinent the construction of an impounding reservoir. The reservoir dam is located at a point directly below the juncture of the two streams and impounds the water along each creek for a distance of approximately 1½ miles, the water from the new reservoir being pumped to the auxiliary reservoir as heretofore. The capacity of the impounding reservoir is approximately 1,000,000,000 gallons or equivalent to 250 days supply, and together with that of the auxiliary reservoir affords a storage equivalent to 255 days on the present rate of 4 million gallons per day consumption.

Clearing operations within and along the margin of the reservoir delayed placing the full reservoir capacity into use until this spring and effects which the impounding of the water may have on its quality and filtration plant operation, have only partially been experienced at the present time, a much too short a period to arrive at definite statements or conclusions. Certain changes have taken place and to such extent as to be especially noticeable.

Both of the streams feeding the reservoir being exceedingly flashy by nature and originating on a water shed composed of clayey soils and rugged topography, a wide and sudden variation in the amount of sediment carried and degree of turbidity existed, with corresponding variation of slightly less degree of the water delivered to the filtration plant. The large amount of storage now available has

[1] Presented before the North Carolina Section meeting, September 16, 1925.

[2] Water Department, Greensboro, N. C.

resulted in a water of more uniform character. Formerly turbidities of 400 to 500 p.p.m. were not unusual in contrast to the present turbidities of rarely more than 30 p.p.m. and during the greater portion of the time 10 p.p.m. and less.

Color increases have been noted, the maximum being 20 p.p.m. whereas formerly it rarely reached 10 p.p.m. The color increase has been anticipated as the site was not stripped of vegetation or top soil. An increase over the amount of color already observed probably will occur, but eventually will be reduced as silting occurs.

A decrease in the H-ion concentration of the water has been noted, necessitating an increased dose of alum to secure optimum coagulation conditions. The average pH prior to the use of the impounding reservoir was 6.8, whereas at the present time the average is 7.0, with a maximum observed of 7.6. No change in the concentration for optimum coagulation of 6.4 has been observed.

Microscopic organisms and algae already have been produced in sufficient number in the short time the reservoir has been in use to indicate our most troublesome problem in the future. Microscopic examination shows a continual increase in number, indicated also by the reduction of the filter runs by 50 per cent over that of the same period last year and the heavy growths within the basins. At times, a distinct fishy odor is noticeable around the basins and on washing a filter, but as yet this has not been sufficient to impart odor or taste to the water. Present indications point to the necessity of proper treatment to hold down microörganisms during the coming year to avoid tastes, odors, and decreased plant efficiency.

THE CALIFORNIA RAILROAD COMMISSION AND THE WATER WORKS MAN[1]

By M. R. Mackall[2]

The relation of the Railroad Commission to the water works man, if he is operating a public utility, is like the poor, it is apparently bobbing up at every turn. The Commission authorizes the beginning of the utility, prescribes its system of accounting, fixes the rates it may charge, supervises its financial operations, such as stock and bond issues, and may fix the value of the properties for condemnation purposes, upon request. In addition, no sale of a public utility can be legally made without authority of the Commission. In fact, one cannot even discontinue or abandon plant and service without the sanction of the Commission.

In spite of this almost complete authority of the Commission its powers are not in any way abused. Too much regulation may be a detriment. If any one thing may be sought out as primarily responsible for the uniform success of public utility regulation by the California Railroad Commission, I believe it is because of the strict adherence to the policy of placing full responsibility upon the utilities and giving them all free rein in individual initiative, operation and management, interfering only when conditions so demand. I do not mean to convey the impression that any responsibility is to be shirked by the Commission through this policy, for such is not the fact. The Railroad Commission has in at least one instance gone to the extent of directing the managing head of one of the largest utilities in the state to leave his San Francisco office and take up his residence in another city until such time as the service conditions then existing in that city were raised to a reasonable standard.

The regulation of water utilities is but one of the many duties placed upon the shoulders of the Railroad Commission. This Commission now has jurisdiction over the rates, rules and regulations of steam and electric railroads, street railways, grade crossings, accidents involving common carriers, safety regulations, wharves and

[1] Presented before the California Section meeting, October 16, 1925.

[2] Hydraulic Engineer, California Railroad Commission, Sacramento, Calif.

warehouses, inland water carriers, oil pipe lines, gas, electric, water, telephone and steam-heating utilities, supervision over the erection of dams by power and water utilities, and also automobile stage and trucking companies, passenger and automobile ferries, and even airplane transportation.

Although somewhat foreign to this subject it is perhaps necessary to a complete understanding of the Commission's activities to see where its powers emanate. The United States Supreme Court in the case of Munn vs. Illinois held that a state had the right to regulate a business affecting the public interest, in this case a grain elevator business. In a later case involving the German Alliance Assurance Company the same court held that this right of the state could not be defeated by doing business under private contracts such as insurance policies, and set up the principle that the states could even regulate the terms of such private contracts.

Heretofore the powers of fixing rates for concerns selling water, gas, electricity, etc., were vested in the county boards and city councils. Valuations were determined in the civil courts. With the general increase in growth of the cities and with the attendant expansion of utilities to large corporations, in many instances covering the entire state, the fixing of rates and the regulation of business became too great a burden upon the resources of the cities and counties and the courts. Furthermore, matters of financing large enterprises demanded on the part of the investing public a stabilizing factor in the form of some uniform and definite policy based upon practical and scientific methods of valuation and rate fixing, removed from the uncertainties resulting from changes in local political administrations. The consuming public demanded that their rights be protected and that each member of the public have some means whereby he could obtain redress in case of necessity without great financial outlay.

The State Constitution was amended in 1911 authorizing the state to delegate to the Railroad Commission the regulatory powers therefore enjoyed by the cities and counties, except that it was not until the year 1914 that the Commission was given sole authority over matters involving the regulation of rates. The authority granted by the Constitution was enacted into law by the State Legislature in the Public Utilities Act.

At the outset it should be explained that the Railroad Commission has no powers or jurisdiction to any extent whatsoever over

water systems owned and operated by municipalities, counties or groups of towns and cities, or legally constituted water or fire districts, or over mutual water companies, nor has the Commission any jurisdiction over irrigation districts. In this connection I might say that I frequently have inquiries from municipally-owned water systems asking if the Commission can acquire jurisdiction over a city water system, if water is served outside the city limits. The answer is that it can not. This specific point was definitely established by our State Supreme Court in a case involving the City of Pasadena.

It may be well to point out at this time that the powers and rights and decisions of the Commission must comply strictly with not only the Public Utilities Act, but also with the laws of the land, and the State and Federal Constitutions. Every order issued by the Commission is subject to the right of review before the Supreme Court of the State and then to the Supreme Court of the United States at the instigation of any party to the proceeding.

As affecting water and irrigation systems, the authority of the Railroad Commission is principally regulatory. It has power upon request to determine value for condemnation purposes, to fix rates, to establish reasonable rules and regulations governing the service of water, to prevent unfair discrimination, to prevent rebates and the granting of special privileges to favored consumers—a thing which rarely happens in modern times, but was once given wide-spread publicity by early practice in railroad operation.

The power of the Commission to regulate rates can not be defeated by private contracts between the utility and a consumer when the commodity has once been dedicated to the public use. In the case of such contracts involving water service the Commission has uniformly disregarded them when such contracts created an unfair discrimination against other consumers. Based upon a decision of the California Supreme Court, the Commission disregarded a contract in which the Spring Valley Water Company had agreed to supply the Newark Station of the Southern Pacific with free water service in consideration for the right to cross the Southern Pacific tracks with a pipe line. The water company was directed to charge the regular rate schedule for such service, upon the theory that such an unlimited contract amounted to an unfair discrimination against the other consumers.

There is a limit, however, to this doctrine. Although the doctrine

of the German Alliance Insurance case is to the effect that private contracts can not alter the right of a state to regulate the sale of a commodity or business affecting the public interest, nevertheless the clash between water rights in this state influenced the California Supreme Court, which has limited this power of the Commission, to apply only when the water has been dedicated to the public use prior to the contracts. This matter was so decided in a case where this commission attempted to disregard certain contracts in the fixing of rates. Thus the question of whether the Commission has the power to disregard and supersede the rates set out in a private contract is simplified by making it necessary to determine only whether the water was dedicated to the public prior to the making of the contract. While this is apparently a simple matter, the fact remains that in practically every such determination the matter never stops until it arrives in the Supreme Court in Washington.

The question of whether a contract whose rates have been superseded by a change in rates legally made by the Commission is made unenforcible as to the other terms contained therein, is now before the Supreme Court of the United States for argument. The California Supreme Court held that the other terms remain in effect. Incidentally, this is a case involving an irrigation company in Butte and Sutter Counties.

Before a private company or individual can operate a water system a franchise must be procured from the city or county in which it proposes to render service, after which an application must be made to the Commission for authority to legally operate. This can be granted only after a public hearing, and is called a certificate of public convenience and necessity, immediately after receiving which the real trouble commences.

A utility may file an application at any time with the Commission for an increase in rates, which can only be granted by formal order after the holding of a hearing open to the public. A request by a utility for a reduction in rates may be granted informally by the Commission without a public hearing, provided no discrimination results. As many of you have already suspected, this removal of complications has not resulted in an epidemic of requests for lower rates.

The time required to render a final decision in a rate proceeding varies from one month to one year from date of filing, depending upon the size of the plant and the amount of work pending before the Hydraulic Division for investigation. It should be remembered that

all affairs and complaints involving every public utility water system in the state are conducted by a department composed of but seven engineers. This is quite a task when it is considered that there are 431 public utility water companies in this state.

This paper cannot cover in any but the most cursory manner the great question of rate fixing and public utility valuation. The matter is highly complicated and involved and has an almost unending variety of problems peculiar to each individual case, many of them not as yet definitely settled by law or even practice.

When application is made by a utility for rate adjustment a complete inventory of the entire properties should be submitted at the same time. If the size of the plant and the financial conditions of the company warrant, this inventory as well as an appraisement of the properties should be prepared under the direction of a competent engineer familiar with valuation matters. The engineers from the Commission after checking the inventory prepare a report giving an independent valuation of the properties and containing an analysis of the costs of maintenance and operation during the past for the purpose of determining the reasonable and proper expenses for the future. The report of the engineers of the Commission must be substantiated by the evidence and subject to cross-examination exactly as any other matters presented to the Commission.

The Commission has generally in the past adhered to the principle that valuations for rate fixing purposes should be based upon the reasonable historical or original cost of the investment in the physical properties which are being devoted to the public use at the time of the proceeding. Lands and rights-of-way, however, are appraised at the present market value. Consideration is also given by the Commission to the present value of the plant as determined by the reproduction cost of the properties less accrued depreciation. It is perhaps advisable, therefore, especially from the standpoint of future financing, for any utility contemplating an application for an increase in rates before the Commission, to present both an estimate of the value of the properties based upon the historial or original cost, and upon the reproduction cost theory less accrued depreciation.

In arriving at a fair value for rate fixing purposes the Commission will exclude non-operative lands, structures and equipment. Intangible values such as going concern, development costs, working capital and water rights are also elements which must be given proper consideration. Thereafter, if conditions so warrant, a schedule of rates

is designed to yield the utility a fair return upon its investment over and above the reasonable cost of operation, maintenance and depreciation. While a fair return under normal conditions is taken by this Railroad Commission at approximately 8 per cent in ordinary utility practice, yet the Supreme Court of the United States has frequently held that a return of 6 per cent may at times properly be held a fair return and will not amount to a confiscation of the properties of the company without due process of the law.

There are of course a great many exceptions to the granting of a full return upon the rate base as found. For instance, it frequently happens that in order to produce a fair return upon the investment a rate would be required which would be so high as to be prohibitive. Unfortunately this situation is by no means rare in this state, especially so far as water utilities are concerned. We have a great number of water companies which have been primarily installed by real estate concerns for the purpose of aiding in the sale of lots. When the real estate operations on many of these subdivisions have arrived at the point where they are no longer lucrative, the operator, if he cannot find a victim to relieve him of his public utility burdens, is required to continue the operation of his plant until such time as the territory develops to the extent where a fair return can be realized through a reasonable rate. There are many water systems starting out which are still in a development state, and in justice to the consumers served by them are not yet entitled to a full return upon the capital invested. There are a great number of irrigation and domestic water concerns which have been the outgrowth of the old mining ditch systems of the early days where the territory served, formerly supporting flourishing communities, is reduced to the extent that the company is unable to meet bare operating costs.

The right of the Commission to fix a rate under these circumstances at a figure less than that which would give a full return upon investment, was recently questioned by one of the power companies in the southern part of the state, which took exception to the ruling of the Commission that the territory served was in a state of development. This matter was taken into the federal courts in California, and while dismissed, resulting in a victory to that extent by the Commission, yet nevertheless was dismissed upon a technicality and the real point at issue has accordingly not been settled by the United States Supreme Court.

A decision by the courts precluding any regulatory body from using

its discretionary power in the fixing of rates would be a calamity and a death blow to public utility regulation. Any system of regulation, whether by courts or administrative bodies, which disregards the great economic principle that there is a limit beyond which the value of the service rendered can not go, is doomed to failure. Although the position of this company was primarily that of questioning certain findings of the Commission to the extent that the rate fixed was actually all that the traffic would bear, and while this company perhaps did not insist that the Commission should be deprived of all discretion in matters of rate fixing, yet nevertheless the principle involved was unescapable, and if carried to its logical conclusion would result in the regulation of rates purely by mathematical formula.

The Commission has, in the designing of rate schedules, tried various methods of determining the charges to be paid thereunder. For a water company the fundamental need is to have a proper amount of money returned to it each year by way of revenues. It is, at least theoretically, only incidentally interested in the manner in which these rates are spread among its consumers. Although the Commission has tried scientifically-designed rate schedules wherein it was necessary to depart from time-honored practice, yet such changes have created such storms of protest as to make the practical application of such rates hardly worth while. The Commission has therefore quite uniformly adhered to the simplest and most readily understood forms of rate structures.

The Commission experienced a considerable handicap in rate fixing by that custom of the early days in which the cities in granting a franchise to a water company would require that all water served to the city itself, including fire service, should be free, Investigations by the California Railroad Commission, as well as the investigations conducted by other regulatory bodies, have determined that the actual cost of investment for the delivery of water for adequate fire fighting purposes runs from 25 to 75 per cent of the entire plant investment. The cost of maintenance and operation of the system is increased proportionately. The difficulty of course lies in the fact that in order to deliver a large volume of water in a short period of time, a greater capacity of distribution and transmission mains, as well as storage and standby equipment, is required than would be necessary for normal domestic service. This Commission at an early stage adopted the principle that free municipal service was

unfair and discriminatory and should be abolished, and proceeded to fix rates to be charged municipalities for fire service, sewer flushing, and for other municipal purposes, upon the theory that the entire cost of operating and maintaining the additional investment required for these municipal functions should not be placed upon the shoulders of the regular consumers, but should be paid for by the property owners who directly benefit thereby. While this principle was unpopular among city officials who were more vitally interested in a lower tax rate than in equalizing the consumers' burden, nevertheless its fairness and reasonableness soon commended itself even to the municipal authorities, and the practice is now firmly established.

The public utility water companies perhaps come in contact with the Hydraulic Division of the Railroad Commission more often through our informal complaint department. This department was organized by the Commission as a result of its general policy to promote a better understanding between company and its consumers and to promote a spirit of coöperation in the general relations of utilities with their customers. While in general the Commission must make a formal order before it can legally demand and require compliance with its suggestions and instructions, yet there are so many matters that can be as readily solved informally without the delay and expense attendant upon formal proceedings, that the commission endeavors whenever possible to settle all complaints informally by correspondence between the parties or by personal investigation when the facts demand it.

During the last fiscal year the Commission settled informally 784 complaints as compared with the rendering of decisions during the same period in 179 formal proceedings requiring public hearings. The informal complaint department has developed into a branch of great importance not only as to economy in saving time and money for utility and consumer, but also by speeding up of final settlement of complaints which otherwise would require formal action and decision by the Commission.

Of the complaints filed with the Commission approximately 40 per cent involve disputed bills, 30 per cent inadequate or interrupted service, 20 per cent service installations and extensions of existing mains for service. The remaining 10 per cent cover complaints against the reasonableness of the rates or the classification charged, refunds under deposits, unjust rules and regulations, and the multitude of other causes which only a water works man can believe

possible, including many that he honestly believes impossible as well.

It is a pleasure to inform you that the complaints coming to the Commission are changing very definitely in character. There is a decided lessening from year to year in the number of trivial complaints coming to the attention of the Commission. Unfortunately for those of us charged with the duty of untangling these usually very difficult problems, only the more involved and complicated matters are now being referred to the Commission for settlement. This simply means that the later companies have most generally adopted the broadminded attitude that good business demands every effort to meet the public fairly and honestly, and that the establishment of a good feeling with the customer through an earnest effort to settle disputes and complaints pays more than one hundred per cent upon the investment, in spite of the monopolistic nature of the business. As a matter of fact this is well illustrated by the fact that the Commission will receive more complaints against some small utility serving a community of perhaps two to five thousand in population than it will receive against the companies serving cities over half a million in population. In most cases this is due to the personal element rather than to service matters. The reason of course is obvious; the larger the utility, the greater is the realization that special efforts devoted to its public relations result in removing friction and reducing operating costs. The larger utilities have all found that special departments organized for the handling of this phase of business is an absolute necessity.

One of the greatest causes of difficulty experienced by the Commission in dealing with complaints is that involving the class of water systems installed by real estate operators to make possible the sale of lots. It is almost the universal practice for these operators to use the cheapest type of materials, adopting quite novel theories of construction, with inadequate sized pipe and usually with little or no storage facilities. Irrespective of whether the system is destined to serve ten people or ten thousand, apparently there is some law, written or unwritten, handed down from father to son, which makes it a felony for any real estate operator to install in a subdivision any pipe larger than two inches or to provide storage facilities more complicated than a 5000 gallon tank, set upon the ground at the lowest point in elevation on the tract. There may of course be some exceptions to this. The difficulty arises when the cream of the lots is

disposed of and the water system becomes a burden. Usually the water supply is inadequate, the service is almost unbearable, and the rates, already insufficient to pay a fair return upon the investment, cannot be increased, for in most cases the charges are already all that the traffic will bear. The consumers of a public utility are entitled to continuous and reasonable service at a just price. The utility is entitled to a rate which will yield a fair return upon its investment. The Commission cannot force any utility to operate its water system at a loss; to do so violates the 14th amendment to the Federal Constitution, which forbids confiscation of private property without due process of the law. This is a problem that is not only not rare, but is a common occurrence.

The solution of this particular problem is apparent to me in only one way, and that is to require the proper type of installation at the outset. Under existing laws this cannot be done. The counties and cities may grant a franchise to a company to construct a water system in the public highways, after which the company applies to the Commission for a public utility certificate. The cities and counties have no authority to demand certain standards of installation and service facilities. As a matter of fact the entire necessity for the procurement of a franchise is easily avoided by installing the water system before the subdivision is accepted by the authorities and the streets dedicated to the public use. As to the withholding of a certificate to operate by the Commission for improper standards of instalation, no such authority is apparent in the Public Utilities Act. The Commission itself is necessarily the greatest offender in this regard, for a majority of those applying for certificates for the operation of a water system have already been supplying a considerable number of consumers, in some instances for several years. To deny the certificate under these circumstances means that the existing consumers in 99 cases out of a hundred will be left entirely without water service from any source whatsoever.

Matters of grave concern to the Commission as well as the water companies are those arising out of demands for service from an existing utility which require the extension of mains or other facilities. This is most acute in cases involving real estate subdivisions. In cases of ordinary extensions to individual consumers the Commission generally requires a water system to extend its mains at its own expense 150 feet for each bona fide consumer, the excess cost to be paid by the applicant, which is to be refunded to him in various ways

when new consumers come on the line within a certain definite time limit. The fairest method of extension would perhaps be to expend a certain definite amount of money for each consumer. However, the varying conditions and the complications arising from keeping track of the costs, make this impractical. The 150-foot rule is the most simple and satisfactory in the end. The time limit for refunds, by the way, is of great importance. A period not to exceed ten years appears to be fair to all parties. In one instance I recall a utility entered into a very elaborate agreement some twelve years ago in which the subdivider put up the money and the water company installed the mains in a large tract, with the provision that when a certain number of consumers were obtained on the tract the entire deposit would be returned in one lump sum. No time limit was fixed. The status of this matter at present is that the company was forced to spend a large sum of money to increase its facilities to serve the tract, which was very slow to develop. At some time in the future the company will be forced to pay a large sum of money in one payment for a system which will need entire replacement within a few years.

The Commission's attitude on extensions to serve completely newly subdivided tracts of land which are to be placed upon the market, is that community growth and expansion should not be throttled by a utility which by law has a monopoly on the service of water to that particular community and is therefore under the obligation to serve all members of the public without discrimination. However, for the protection of the existing consumers the utility should not endanger its facilities or its financial structure by assuming a part of the risk in an independent and speculative business venture. If the tract is a failure, the investment, if made by the utility, may very properly be disallowed to the extent of this failure, in a rate fixing proceeding before the Commission. There are several water systems in the state where extensions covering large tracts have been made as the result of misguided enthusiasm, on which years later there were still more than one thousand feet of distribution mains to each consumer. One hundred feet is normal. Obviously such ventures do not pay dividends, especially when the time for replacement arrives. The reasonable thing to do then, is to protect the present consumers of the water company by requiring the applicant for this type of extension to deposit with the utility the estimated reasonable cost of the entire installation, to be refunded over a definite period from a

percentage of revenues received from the extension when the development of the tract so warrants it.

The difficulties which arise here are mainly over the size of the mains and the type of materials which should be paid for by the applicant. The size and materials should conform to the general practice of the utility as modified by any peculiar local conditions existing on the new tract. It would be unfair to require an applicant to pay for a twelve inch main to be used for other parts of the system, as it would be equally unfair to charge for eight inch pipe where under similar conditions the practice has been for the company to use four inch and six inch mains. It would be equally unfair to require payment for the installation of cast iron pipe where the remainder of the system is of standard screw or riveted steel pipe, although in the matter of materials this may be qualified in certain cases where there is immediate danger of the territory served by the utility being taken over by a municipally owned water system having certain definite standards of water works construction.

The question has frequently been asked by water companies operating on flat rate schedules whether formal request is necessary for the installation of water meters. In reply to this it should be stated that no authority is required from the Commission to install meters. The complications however arise when the attempt is made to charge for the measured service. This may be done if the company has already a rate for measured service, but where there is no such rate the company is practically precluded from charging more than the existing flat rate, for the reason that to do so would amount to an increase in the established rates. This cannot be done without authority from the Commission. Where no meter rate exists, therefore, it will be necessary to apply to the Commission for the fixing of a rate for metered service.

The Commission has been severely criticized in certain communities for its attitude in recommending that all water should preferably be sold through measuring devices, except in cases of very small utilities and where there happens to be an unlimited supply of gravity water. This opposition is of course a relic of the early days when most people had their own private water supply and were free to use the water as they saw fit. One of the greatest obstacles to water works operation is this same general feeling that water should cost but little to deliver to the home. As a matter of fact the delivery of adequate water service in this state is increasing in seriousness and

complexities each year, particularly in the water supplies of all of our larger cities. When one considers that facilities must be provided to give each individual living anywhere in the community the privilege of going to the faucets in his home at any hour of the day or night and finding available an unlimited supply of fresh, pure water, the value of that service is the vital factor, and the cost to produce and maintain that service is now a considerable burden. Anything which will reduce this cost is a desirable thing to the consumer as well as the utility. Selling water upon the basis of payment for the amount used reduces this cost by reducing waste, reducing main and storage capacity, and by reducing pumping expenses where pumping must be resorted to. Above all it puts the operations upon a definite and business basis. Curiously enough there is practically never any objection before the Commission to the metering of electricity or gas service, yet there is frequently very bitter opposition against metering water service. However, once the measured system is installed, the prejudice usually disappears, especially when all services have been metered.

The Commission has frequently before it complaints that partial metering results in a discrimination against metered consumers in favor of flat rate users who have no limit placed upon the amount of water that can be used for a given monthly charge. In this regard it should be stated that this practice is a discrimination and one that in certain instances can be a very unfair one. However, no rate schedule can be devised which will be free from discrimination; but unless this apparent discrimination is unfair and unreasonable, for all practical purposes it may be ignored.

When meters are installed upon those consumers using large volumes of water or requiring intermittent supply or upon those who indulge in wasteful practices, there is to all practical purposes no unfair discrimination against them if they pay for all the water actually used at a reasonable rate fairly comparable with the charges for flat rate service. The remaining difficulty in discrimination, resulting from a mixed flat and metered service, is to use good judgment in metering consumers so that of two neighbors of the same class one will not be needlessly antagonized by being placed upon a metered basis, while the other remains upon the flat rate charge for no logical reason. If this must be done, please settle the war yourself and do not refer it to the Commission.

An interesting recent development in the arts has resulted in

bringing additional joy into the care-free life of the water works operator. I refer to the battery type of underground lawn sprinkler designed to relieve the householder of all excessive physical and mental fatigue. From an operating standpoint, this system demands a good pressure and sufficient capacity to serve a large volume of water for a short period only, and therefore usually requires replacement of the former service with at least a two-inch connection, including the meter.

The consumption of water is not as great as the size of the service connection would normally warrant, and to help matters out the sprinkling is indulged in only during the summer season. An epidemic of these sprinkling systems in one or two blocks is liable to spell disaster for the usefulness of the street main formerly adequate. The only remedy for this situation is to readjust the monthly minimum charge for the size of the connections used for this service so that revenues will be produced commensurate with the cost of the facilities necessary to render this service. Another method would be to fix a special minimum rate for services where this type of sprinkling device is used.

The Hydraulic Division is now endeavoring to work out a new system of general rules and regulations governing the relations of general service matters with the water consumers. Our present rules and regulations are general in character, but since their adoption conditions have changed in many instances, so that revision will undoubtedly prove beneficial. In this regard the thought occurred to me that information on the similar practices of other utility commissions would be of great value, consequently letters were written to all such boards in the United States. The results were quite surprising. Although I have apologized for so many years over our own rules and regulations that I had almost begun to suspect they could stand considerable improvement, I discovered that only a handful of the other commissions had any themselves and most of them declined to accept any responsibility for their efforts. After looking them over I am frank to state that our own did not suffer any by comparison.

Seeing that I have carefully refrained from mentioning the Railroad Commission up to this point, I might as well state at this time that I believe the people of this state are particularly fortunate in having had appointed to the Commission very able and broadminded men who through unwavering fairness and through the constant

endeavor to solve their many diverse and complicated problems by the applicaton of sound common sense methods have created a regulatory board in this state which I am proud to say is generally conceded to be second to none among utility commissions in this country. The decisions of this Commission are given great weight as authorities and precedents throughout the entire United States. In view of the comparative newness of our western country this is indeed not only a compliment to our state and its institutions, but it is of course one of the reasons why regulation by this Commission, I sincerely believe, has been uniformly successful. Regulation to be a success and to survive must be sound, sincere and unbiased. Only when this is the case will the public, the utilities, and those members of the public who invest their money in the securities and stock of the utilities be satisfied.

My experience throughout the state with many water utilities has led me to believe that certain practices are sometimes overlooked by the operators which will prove of great benefit if adopted.

In the first place, meet your consumers more than half way and grant them the utmost consideration, even though they may be wrong. A man available to investigate promptly service and other similar complaints on the premises will more than repay the utility for the effort. The larger utilities have found that large dividends by way of good feeling and increased gratefulness are paid by having available a man who can advise the consumers tactfully as to certain of their service problems.

From an operating standpoint a simple and uncomplicated bookkeeping system that will reflect the financial status of the utility at any time desired without the aid of a corps of valuation engineers and expert accountants is a most valued adjunct to the business, and while neither difficult nor costly to maintain, is, I regret to say, all too rare among water companies.

Too many water utilities neglect the keeping of large scale service maps showing the tied-in locations of pipe lines, gates, hydrants and services. While this is a simple matter to keep up to date when once started, many a company has spent more money prospecting for gates and mains with the assistance of one of the oldest employees who thought it was laid about in line with some house, than would be required to keep up the records for several years.

Whenever the finances of a plant will warrant, the addition of a competent engineer to the organization will amply repay the utility.

The keeping of simple and clear cost account records of all repairs, replacements and new installations of all kinds will be of the utmost value for the purpose of estimating future extensions and improvements as well as throwing light on past experiences. Remember that to be of value cost records should be prepared by practical engineering methods and not from the mere book-keeping standpoint.

Where financial troubles are becoming apparent and where the majority of the water is delivered upon a measured basis, the annual tabulation of the water consumption of the consumers will throw very definite light upon changed service conditions, will show where the water goes, and will instantly indicate whether the use of water is such that existing rate classifications are no longer properly spread and are in need of modification or readjustment. As a matter of fact all rates fixed by the Commission are based upon a study and analysis of the water use.

The experience of the Railroad Commission has clearly demonstrated that without exception a utility in financial distress means dissatisfied and complaining consumers. Remember therefore that before conditions arrive at the breaking point the utility owes the duty to its consumers, as well as itself, to lay its difficulties before the Commission, which is not in any sense a board of inquisition, but on the contrary at all times has its entire facilities, legal, financial and engineering, at the disposal of the utilities as well as the public.

LIABILITY FOR WATER-BORNE DISEASE[1]

DECISIONS OF THE SUPREME COURT OF THE STATE OF WASHINGTON RELATING TO POLLUTED WATER FURNISHED BY THE CITY OF EVERETT

By Homer O. Blair[2]

The Supreme Court of the State of Washington has just rendered decisions in two cases confirming judgments of the Superior Court of Snohomish County for damages granted by juries for wrongful deaths of persons alleged to have died from typhoid fever contracted by drinking water furnished by the city of Everett. One of the cases is that of Victor Aronson, as Administrator of the Estate of Senobia Aronson, Deceased, v. The City of Everett, and the other one is Gertrude Mary Roscoe, as Executrix etc., v. The City of Everett. Both of the cases are based on similar facts and for this reason are reviewed together.

In the Aronson case the $6000 verdict was divided by the jury, $2000 to the surving husband, and $2000 to each of the children. The court ruled that the award was not excessive as the record showed that the husband has been deprived of the services of his wife for a period in excess of thirty years. In regard to the children the loss of the care and protection that they would have received from their age up to the age of majority was found by the jury to be worth $2000 each.

The record shows that, within a comparative short time during the summer of 1923, there were about eighty cases of typhoid fever and a number of deaths therefrom in the city, on account of which a number of claims or suits have been filed against the city.

The city of Everett was engaged in the business of supplying

[1] Prepared at the request of the Editor. Material obtained from the advance sheets of the Washington Decisions of the Supreme Court, published by the Law Digesting Company, Olympia, Washington. For further data on legal aspects of similar cases, see the Manual of Water Works Practice, Chapter I.—*Editor.*

[2] Consulting Engineer, Tacoma, Washington.

water for domestic and drinking purposes to the citizens for a consideration and during the month of July, 1923, the water became impure, unwholesome, polluted and dangerous to life and health. The complaint charged that the condition of the water was known to the defendant, its officers and agents who were charged with the duty of keeping and maintaining the water in a pure condition, or with the exercise of reasonable care and inspection would have known the condition of the water. It is charged that the impure water was furnished for a period of six weeks prior to August 14, 1923, and the drinking of this water caused the death by typhoid fever of the persons mentioned in the suits.

In these cases it was established that polluted water was permitted to pass into the city mains through a by-pass connection at the Eclipse Mill Company's plant. On April 11, 1923, a 6-inch main was laid to connect two laterals, and, when the connection was made it permitted free circulation of water to the city users in the district served, and also a better service to the Eclipse Mill Company. Prior to this time the company was connected with the city water system, although it had its own pumping system connected with the river. The testimony showed that the pollution of the city water came through the mains of the Eclipse Mill Company's plant, which was situated on the Snohomish river. The water taken by the mill company from the river was not fit for human consumption, and it was not intended that this water should flow into the city mains for use by the inhabitants of the city. There was a series of check valves which were intended to prevent this water getting into the city mains. However, there was a by-pass which allowed the water to go through the mains without going through the check valves that had been installed. There was a gate valve in the by-pass and it was supposed to be kept closed to prevent water from circulating from the mill through the city mains. In addition, the city mains generally carried a higher pressure than the mill company's mains. During the epidemic of typhoid fever in Everett during the summer of 1923 an investigation was made which finally resulted in finding the gate valve open, and that the pressure in the city mains, temporarily lowered by heavy use of water sprinkling, was permitting the polluted river water to enter the city mains, resulting in typhoid fever.

It was the contention of the city that, at the time the 6-inch main was connected up in April, 1923, the Eclipse Mill Company

had agreed to remove the by-pass, and that the new pipe line was put in for the convenience of the mill to secure a complete circulatory system throughout. There was no issue before the jury as to whether or not the work was done in a workmanlike manner. The question as to whether this connection was made at the request of the mill company, or that they paid a part of the cost or whether they had agreed to remove the by-pass or whether a part or all of the valves and pipe lines were upon the mill company's property, were not matters material to the issue. It was negligence for the by-pass to be left there when there was no need for it, especially with the gate valve open. The officers of the city did not seriously contend that this by-pass should not have been removed.

The city claimed that there was no evidence that Senobia Aronson drank any of the water. But her husband, who was plantiff in the action, testified that he was afflicted at the same time as his wife, and when asked "where did you get your water," answered, "city water."

There was evidence that the city never inspected the valve in the by-pass from the date of its installation of the new main on April 11, until the 25th day of July, 1923; that the city made no effort during that time to determine whether it was closed, or to determine if it had been removed by the mill company. The situation is not parallel here with those cases where the chance of pollution is small and incidental, as, for instance, where a city watershed covers a great deal of territory and constant policing would be required to prevent contamination. In this case the city permitted water to be taken from a point close to where city sewers emptied into a line which was physically connected with all the users in the district. Nothing but the closed gate valve could prevent the polluted water reaching the consumers. The ease with which the valve could be sealed or the by-pass removed, and the imminent danger to be apprehended by failure so to do, are strong factors in the question of the city's negligence. It thus became a question of fact for the jury to determine, in the light of all the evidence in the case, whether or not the city was negligent on leaving this by-pass with the gate valve; whether it was negligent in its failure to inspect at any time thereafter, and whether it was negligent for failure to ascertain and remedy the condition of the polluted water after notice had been given it.

Some contention is made that notices were given to the health

inspector, and that such notice should not be construed to be notice to the city as far as the water department was concerned. It seems to the Supreme Court that complaints made to the health department were at least some notice to the city, for the complaints were made to the particular officers of the city selected to handle matters relating to the public health, and who were qualified to determine the city's course of action. Indeed, it might well be said that the health officer would be far better qualified to act upon such information than an officer of the water department whose knowledge might be confined to the physical construction of the plant rather than to the matter of precautions necessary to be taken to secure immunity from pollution. But the question more clearly is whether, considering the necessary close relationship between the city health department and the purity of water furnished by the city to its users, it can be found that notice reached the responsible authorities of the water department. In any event, however, the evidence showed the polluted condition of the water for a sufficient length of time to make it a question for the jury as to constructive, if not actual, notice to the city.

The city insists that the complaint was drawn on the theory of an implied warranty, and argues strenuously that the city in furnishing water to its users does not guarantee its purity and wholesomeness. Reliance is had upon the following cases, Canavan v. Mechanicville, 229 N. Y. 473, 128 N. E. 882, 13 A. L. R. 1123, and Green v. Ashland Water Co., 101 Wis. 258, 77 N. W. 722, 70 Am. St. 911. While both cases hold that a city furnishing water to its inhabitants does not impliedly warrant that the same is pure and wholesome, yet both of these cases recognize that the failure to properly inspect the water so as to keep it free from contamination is negligence. There is ample authority that a city engaged in furnishing water, electricity or other kindred services to its inhabitants for a profit is liable for negligence the same as any private corporation engaged in the same business; that the city does not act in a governmental capacity, and that there is an implied warranty that the water is fit for human consumption. Hayes v. Torrington Water Co., 88 Conn. 394, 92 Atl. 406; Jones v. Mt. Holly Water Co., 87 N. J. Law 106, 93 Atl. 860; Hamilton v. Madison Water Co., 116 Me. 157, 100 Atl. 659, Ann Cas. 1918D 853. As to which rule should be adopted, it is not necessary for the higher court to determine in this action, since it is held that the complaint is based upon the ground of negligence and not on implied warranty.

ABSTRACTS OF WATER WORKS LITERATURE

FRANK HANNAN

Key: American Journal of Public Health, **12:** 1, 16, January, 1922. The figure 12 refers to the volume, 1 to the number of the issue, and 16 to the page of the Journal.

The Ogee Spillway Section Defended. JOEL D. JUSTIN. Eng. News Rec., **94:** 945, June 4, 1925. Discussion of A. F. Meyer's paper (cf. this J. **14:** 4, 363) in which ogee form of spillway is defended. Purpose of this type of profile is to protect dam itself and foundation immediately under dam from direct injury due to impact of falling water, and when properly designed and constructed it has successfully fulfilled this function. Cross-section of Junction Dam on Manistee River is reproduced, illustrating use of combination of flexible apron and tumblebay to destroy excess energy and reduce scour. —*R. E. Thompson.*

Destroying Energy Below Overflow Dams. HORACE S. HUNT. Eng. News Rec., **94:** 945–6, June 4, 1925. Discussion of paper by A. F. Meyer (cf. this J. **14:** 4, 363) in which methods of destroying excess energy below dams experimented with by Fargo Engineering Co., as exemplified in dam on Muskegon River in Michigan and Junction Dam on Manistee River, are outlined. —*R. E. Thompson.*

Errors in the Use of Thermometers. B. BLOCK. Chem. App., **10:** 9–11, 19–20, 1923. From Chem. Absts., **17:** 1561, May 10, 1923. Thermometers for taking temperatures inside vessels or pipes should have long stems and narrow bulbs with thin walls and be inserted well within walls of apparatus. In taking temperatures of liquids flowing through pipes thermometer should be inserted at bend in pipe so that flow is against end of bulb.—*R. E. Thompson.*

Pouring Concrete in Zero Weather. C. N. SHANLY. Cont. Rec., **39:** 126–8, 1925. Methods of concreting in cold weather are outlined. Cost of protecting concrete during 100-day period during which average temperature was 14°F. and maximum and minimum 70° and −30° respectively, was approximately $0.50 per cubic yard, 25,309 cubic yards being poured during the period. Mass concrete was found to set satisfactorily when placed at temperature of 40–45°F., if suitably protected. Following observations by H. G. COCHRANE included. (1) Fresh concrete makes perfect bond with concrete frozen before setting and still in frozen condition. (2) Test specimens subjected to "below zero temperature" and frozen before initial set attain average of 70 per cent of strength of similar specimens cured under most

favorable conditions. Those frozen after initial set attain 80 per cent of strength, and those frozen immediately after final set 95 per cent. (3) Concrete subjected to second freezing is seriously damaged. (4) It was found that unprotected portions of concrete froze to depth of 2–4 inches overnight, and to depth of 12 inches in 2 weeks. After covering with fresh concrete, temperature of frozen portion and also of fresh concrete immediately above joint rose to 70°F. within 12–20 days.—*R. E. Thompson.* (*Courtesy Chem. Abst.*)

Testing and Placarding Roadside Waters in Pennsylvania. EARLE L. WATERMAN and H. P. DRAKE. Eng. News Rec., **94:** 645-6, 1925. During summer of 1924 state-wide survey of water supplies along highways of Pennsylvania was carried out by State Dept. of Health. Sanitary survey of each source was made and samples from those considered satisfactory were examined in field laboratory. Survey involved in excess of 2000 miles of highways and 1200 sources of supply; 841 supplies being sampled and 407 found satisfactory and conspicuously placarded as source of "safe drinking water." Of 275 dug wells examined, 104, or 38 per cent, were approved; of 248 drilled wells, 199, or 80 per cent, were approved; and of 162 springs, etc., 104, or 65 per cent, were approved. Study of results indicates that geologic structure was determining factor in most cases, 75 per cent of sources found unsatisfactory being in limestone and broken shale formation, while only 13 per cent of approved sources were in such formation. All sources will be reexamined before approval signs for 1925 are granted.—*R. E. Thompson* (*Courtesy Chem. Abst.*).

Ground Water Supply at Moscow, Idaho. F. B. LANEY, V. R. D. KIRKHAM and A. M. PIPER. Idaho Bureau of Mines and Geology, pamphlet No. **8:** 13 pages, maps and sections (mimeographed), December, 1923. Report of study to determine whether ground water supply is sufficient for future needs of Moscow. Water occurs in several beds of alluvium lying between beds of basalt. In 30 years head in wells in region has declined about 44 feet, and yield has decreased considerably. Quantity of water available for recharge of ground water reservoir is estimated to be more than twice present consumption. A plan is outlined to intercept entire ground water flow as far as possible by drilling a barrier of four wells across direction of flow and making explorations to develop deeper horizons than those now used.—*David G. Thompson.*

Ground Water in Santa Clara Valley, California. WILLIAM O. CLARKE. U. S. Geol. Survey Water Supply Paper **519:** pp. 320, 19 plates and 20 figs., 1924. A comprehensive report on ground water conditions in important irrigation region of Santa Clara valley, including also data on physiography, geology, precipitation, and stream flow. After describing general conditions affecting occurrence of ground water, estimates are given of quantity annually available in five different parts of valley. Two methods are used in making these estimates: (1) water-level method, by which available pore space in material in which fluctuation occurs is calculated from well logs

and from these data quantity of ground water gained or lost in the fluctuation is estimated; (2) absorption method, by which quantity of water lost from streams by seepage into alluvium is determined by discharge measurements at different places. Report contains data in regard to nearly 1000 wells, including frequent observations on fluctuations of water table in number of them for several years; maps showing isohyetose lines, location of wells, areas of artesian flow, contours of water table, and other ground water conditions; and graphs showing profile of the water table on different dates.—*David G. Thompson.*

On the Variations of Consumption of Water in Towns. JOHN BOWMAN. Water & Water Eng., **26**: 228, June 20, 1924. Trans. Inst. of Water Engineers, **29**: 29, 1924. Growth of consumption and population from 1870 to 1923 in Edinburgh (Scotland) and district shown in figure. In 1870–71 population of about 260,000 used daily about 6,100,000 Imp. gals.; in 1922–23, respective figures were 460,000 and 21,000,000. After introduction of Moorfoot supply end of 1879, consumption showed immediate increase of about 33 per cent; after introduction of Talla, in 1904, upward tendency of consumption curve was rapid in next 7 years and gradual thereafter. Increase in domestic consumption has not been as great as in industrial. In 1871–72, trade and shipping accounted for 1.98 gallons per head per day or about 6 per cent of total; at present they take about 12 gallons or about 25 per cent of total. Present domestic consumption per head per day is given as 34.33 Imp. gals. as compared with 29.12 gallons 40 years ago, an increase of 5.22 per cent. Twelve years ago meters were placed on the 9 trunk mains delivering water into city, which for ensuing 9 years constituted entire supply. Analysis of consumption variation during this period yields following results: (1) Quarterly; variation is not 1 per cent above or below average of 25 per cent. (2) Day of the week; highest average daily consumption is about 15 per cent of total weekly consumption; and lowest, Sunday, is 12 per cent. (3) Daily; rises to nearly 30 per cent above average and falls to 70 per cent of average. (4) Time of day; from about 8 a.m. to 8 p.m., consumption is above daily average, being about 70 per cent of total daily supply; it is at lowest from 2 a.m. to 6 a.m. when it varies from 50 to 60 per cent of daily average. Table is given showing average daily consumption per head for domestic use in 62 areas with total population of 15 millions; it ranges from 14.26 to 70 Imp. gals.; in 32 cases it is 25 gallons or less; in 30 cases it is above 25 gallons; 18 of the 29 higher consmptions are in Scottish towns where houses are provided with larger number of fittings as compared with similar houses in English towns. Figures are also included to show increase or decrease in consumption during periods ranging from 5 to 60 years. In 38 areas there has been an increase due to substitution of water for earth closets and increasing installation of baths and other fittings. During 18 years, per capita consumption in London increased only 1.53 gallons from 33.54 to 35.07 gallons. In Durban, South Africa, daily domestic consumption per head is about 24 gallons out of total daily average of 60 gallons. PARKER considers that for the requirements of British climate a city is well supplied which uses (abnormal waste apart) about 22–25 Imp. gals. per head per day for all

purposes, of which 15–18 gallons would be for domestic use. Allowing for waste this would amount to 30–35 gallons per head per day (36 to 42 U. S. gallons). In Edinburgh, domestic consumption per head per day varies greatly in different institutions and buildings: tenement district, no baths, 6.52–8.72 gallons; asylum, 57.7–60.8; boys boarding school, 39.7; hospital, 110.5; hotels, 80–151. Three tables contain data on velocities and flows through 73 mains of waterworks in Great Britain. In most cases velocities are under 3 feet per second.—*Geo. C. Bunker.*

Glasgow Corporation Waterworks. J. R. SUTHERLAND. Trans. Inst. of Water Engineers, **29:** 53, 1924. Brief account of origin and development of works. Loch Katrine works were opened in the latter part of 1859 by Queen Victoria. At that time water was conveyed to service reservoir at Milngavie through old aqueduct of 1855. Act of 1882 authorized duplication of this reservoir by construction of that of Craigmaddie. Act of 1885 provided for new aqueduct, increased storage in Loch Katrine by raising water level 5 feet (making total available storage depth of 12 feet), and duplication of mains from Milngavie reservoir to and throughout city. These works were constructed gradually and last stage of work was finished in 1903. Shortly afterwards old aqueduct, in use for about 45 years, was completely overhauled. Work on new mains to city was finished in 1916 with result that eight 36-inch mains now carry water into city from service reservoirs. Loch Arklet Works, adding 14–15 million Imp. gals. per day to supply available from Loch Katrine, were started in 1909 and opened in 1914. In 1915 scheme was authorized for storing and diverting into Loch Katrine the large streams of the Glenfinlas gathering ground which will add 14.5 million gallons per day. In 1919, a 5 foot increase in storage depth in Loch Katrine was authorized, making a total storage depth of 17 feet for water supply purposes. Gorbals works were authorized in 1846 to supply large area on south side of city but can only supply about one-fifth of present requirements in this area. Recently Corporation completed purchase of lands surrounding and draining to Loch Katrine and Loch Arklet, amounting to 24,110 acres—excluding the area of the lochs themselves—at cost of £71,850. City has now complete control over watersheds, and freedom to extend and alter works and roads without being subject to serious restrictions and claims for compensation and damage which arise when land is privately owned. Illus. by sketch map.—*Geo. C. Bunker.*

Iron Deposit in Cast Iron Pipes. J. R. Fox. Water & Water Eng., **26:** 497, Dec. 20, 1924 & **27:** 21, Jan. 20, 1925. Trans. Inst. of Water Engineers, **29:** 59, 1924. Deals with incrustation in pipes carrying certain soft waters from Pennine range. Water (subjected to ordinary sand filtration) is clear with slightly yellow color, with 104 parts of total solid matter, 14.3 parts chlorine, no nitrites, 0.4 parts nitrates, 0.7 parts poisonous metals (lead, etc.), 39.3 parts hardness, 0.42 parts of iron (Fe) per million. pH of raw water is 6.5. (This sample was taken from lead service pipe which accounts for comparatively large amount of poisonous metals of which lead undoubtedly forms greater part.) Incrustation, or fur, is deposit, mostly iron bac-

teria, from water; it can be easily removed, leaving original coating; if pipe is heated and lightly hammered deposit will drop off; there is no action on iron of pipe. Analysis of deposit is: loss on ignition, 16.48; silica, 0.95; total iron as iron oxide, 79.82 per cent; alumina, etc., trace; manganese, trace. A black slime forms first all over pipe followed by continual deposition in form of reddish brown lumps. Presumably the slime is, or contains, Crenothrix which removes iron from water and thus produces incrustation. A 12-inch trunk main, laid about 55 years ago, has been reduced to 10½ inches. Incrustation is greater in distribution pipes in which there is no steady night flow; it is usually less at dead ends and greatest at bends and in hollow places; it is not regular. In a 3-inch pipe over 50 years old (not a dead end) there was a complete stoppage at one point, remainder being reduced to ½-inch or less. In general ½ to 1-inch of incrustation will form all around pipe in about 30 years; smaller distribution pipes are practically useless for proper supply in from 30 to 40 years; those of larger diameter will lose 50 per cent, or more, of their discharging capacity. Incrustation is a serious matter for three reasons: it causes shortage of supply; it reduces fire protection; and it makes water harder. Some mains, having got to state described, are relaid on account of deterioration from outside causes, but in case of majority, iron of pipe is quite sound and has many years of useful life. No rule can be laid down for relaying; some mains 80 years old are perfectly sound; others 40 years old could not be scraped owing to softening of metal from external causes. Generally speaking, of mains so badly furred as to require attention, writer proposes to relay those on which frequent bursts have occurred and those in vicinity when over, say, 50 years old, and to scrape the rest, irrespective of age. No doubt in ordinary times relaying as against scraping would take place on larger scale, but owing to comparative costs, need of all possible economy, and lengths of mains to be attended to, amount of relaying has to be kept to minimum. Cost of scraping varies with amount of fur, or other obstruction, etc., but it should not exceed 1s. 2d. to 1s. 6d. per lin. yard, according to size and state of pipe, and is therefore not more than about 14 per cent of cost of relaying smaller pipes, proportion becoming less as pipes increase in size. Use of silicate of soda is briefly discussed but no definite conclusions given; lime treatment in use for prevention of plumbosolvency will reduce deposit of iron bacteria, iron being deposited in form of ferric hydroxide, but this treatment will cause trouble if carried out after filtration as deposit will take place in mains. Use of concrete or cement-lined pipes has been suggested and writer has put in sections of such pipe but they have not been in use long enough to furnish comparisons with unlined pipe. Recently samples were taken of a piece of straight concrete lined pipe, 6 inches diameter, and of an unlined bend which had been in use 1 year; latter had commenced to fur, but only slightly; there was nothing on piece lined with concrete except that it was slightly slimy. One of firms lining pipe found that certain amount of furring took place, but loss of carrying capacity was much smaller than in unlined pipe. Where incrustation is caused from iron in water, best remedy would seem to lie in its removal before the water enters pipes, by three methods; use of coagulants; filtration through polarite, or similar material; or aëration. **Discussion.** F. W. MACAULAY (Birming-

ham) pH of raw water from upland gathering ground of River Elan in Mid-Wales was about 5.5; treatment with small dose of silicate of soda raised it to 9.0 or 9.5; silica content was very low, about 5 p.p.m. Incrustation of cast iron and steel mains forming the siphons on Elan aqueduct was very serious. From experiments now in progress there seems no doubt that metal of pipe is very active agent in incrustation. Witness following facts: (1) Elan aqueduct consists of alternate lengths of brick or concrete-lined aqueduct and siphon mains in cast iron or steel. Incrustation and slimy deposit are confined entirely to latter, except for its occurrence upon any iron or steel surfaces in brick or concrete-lined lengths. (2) Nodular incrustation is greatest on invert, where coating of pipes had received most damage during laying of mains. Although each nodule spread over large area of apparently sound coating, under centre of most nodules examined was found a fault in coating or paint, often a hole so minute as to be invisible to naked eye, and in many cases cast iron under and around this hole had become so soft that it could be cut out with penknife. Metal of steel surfaces was almost invariably pitted under nodules. (3) Some 3 or 4 years ago a length of 42-inch cast iron double main was scraped. Result was corresponding immediate increase of capacity. About same time a parallel length of concrete-lined pipe, 60 inches in diameter, was laid. Nearly whole of increased capacity of cast iron mains had since been lost through re-incrustation; concrete-lined main had lost no capacity and showed no sign of incrustation or of slimy deposit. Analysis of nodules: moisture, 44.9; calcium sulphate, 3.33; magnesium sulphate, trace; silica, 0.55; carbon dioxide, nil; ferrous oxide, 12.9; ferric oxide, 39.32 per cent. Crenothrix and allied bacteria were found in slime. Experiments are being carried out with silicate of soda, in hopes of beneficial results from its use in the way of preventing, or at least of delaying, corrosion of the cast iron and steel. Conclusion is, from 20 years' observation of action of Elan water on concrete and iron surfaces respectively under similar conditions, that in concrete-lined pipes there would never be anything approaching amount of incrustation and deposit to be found in very few years in cast iron and steel pipes, and that, therefore, on account of assured maintenance of discharging capacity of first-named, any reasonable amount of extra first cost incurred by their adoption is more than justified. This applies to pipe of small diameters. For pipe of 42-inch diameter and upwards, properly designed steel and concrete pressure conduits could be made as cheap as, or even cheaper than, all metal cast iron or steel mains. Scraping is temporary palliative, often costly, and possibly destructive. G. R. Collinson (Tees Valley) said there were no iron or nodular incrustation of any kind in concrete pipes put in in 1905 at Swansea, although on lengths of steel and iron pipes forming part of same trunk main there was considerable incrustation. Water was from peaty moorland with characteristics similar to those of the analysis of water given by Mr. Fox. M. J. Buckley (Belfast) stated that 5-inch c.i. main, about 4½ miles long and 60 years old, was as clean to-day as when laid; water of 9 degrees (129 p.p.m.) hardness flowed through it. In about 11 miles of 36-inch c.i. and steel pipe laid as siphons about 25 years ago and carrying same water, nodules in steel pipe were not 25 per cent as many as in c.i. T. H. Tyson (Boston) men-

tioned that, prior to installation of chlorinating plant in 1922, pipes in use for about 76 years had developed incrustation, but since 1922 deposit had become somewhat softer and tended to dissolve. Mr. Fox stated that general manager of large Canadian works had informed him that by chlorinating he had not only prevented furring, but had got rid of existing fur. G. MITCHELL (Aberdeen) said that, while lining pipes with concrete gave no absolute guarantee against incrustation, the very large experience in America and the smaller experience in this country and the Continent pointed to its being successful in most cases. Dilute solution of sodium silicate had been found very effective, when applied under pressure, in reducing permeability of spun concrete pipes; he was trying it on a considerable length of large pipe.—*Geo. C. Bunker.*

Standard Arrangements for Impulse Turbines. S. C. O'GRADY. Water & Water Eng., **26:** 49, February 20, 1924. Directions for arriving at suitable lay-out and preliminary dimensions of turbine and pipeline for small hydroelectric plant. Illus.—*Geo. C. Bunker.*

The Taking of Inshore Soundings. ERNEST LATHAM. Water & Water Eng., **26:** 56, February 20, 1925. To those engaged on structural work such as piers, jetties, quays, and dolphins in tidal rivers and estuaries, taking of accurate soundings plays all important part. Article is purely practical and is written after experience of those pitfalls which marine surveyor is likely to encounter. General aspect of marine survey work of this character was covered in article in "The Engineer," page 614, June 2, 1922, in which six methods of taking inshore soundings were given. Illus.—*Geo. C. Bunker.*

The Measurement of the Discharge of the Nile through the Sluices of the Assuan Dam. (Second Paper.) H. E. HURST and D. A. F. WATT. Water & Water Eng., **26:** 61, February 20, 1924. In previous paper (Proc. Inst. C. E., ccxii, p. 228) method was described of measuring in masonry tank the discharge through certain sluices of Assuan Dam, and thence determining whole discharge of Nile. Method can only be applied during low stages from January to July and is not applicable in flood time. This paper describes the first measurements of higher stages of Nile. Current-meter of propeller type and of especially stout construction was used to map velocity distribution in the sluices. By doing this in a type A sluice, the discharge of which has been measured in the tank, the current-meter is rated against absolute volumes of water. Knowing area of cross-section of sluice-jet, relation between velocity of water and revolutions of current-meter is obtained. Repetition of process in other sluices enabled discharge of these to be inferred. Velocities ranged from 3 to 6 meters per second, and over this range rating curves of current-meters were linear. A good degree of accuracy was obtained, both in rating and in actual measurements of unknown discharges.—*Geo. C. Bunker.*

Water Power at Greenock. JAMES MACALISTER. Water & Water Eng., **26:** 219, June 20, 1924. Trans. Inst. of Water Engineers, **29:** 15, 1924. Green-

ock Corporation Waterworks holds unique position among municipal water undertakings of Scotland, inasmuch as, besides furnishing filtered water for domestic and trade purposes, it supplies large quantities of unfiltered water (a) for power purposes, by means of aqueducts and falls, and (b) for trade purposes, by means of pipes. At present Greenock water undertaking comprises 19 reservoirs, having total storage capacity of 4320 million gallons, and catchment area extending to 10,000 acres. Two water power streams are fed from this storage capacity; one, known as the Eastern Line of Lead, has 19 falls and 12 millsteads; the other, known as the New Eastern Line of Lead, has 7 falls and 7 millsteads. Total of 1,575 H.P. is available from the two leads. Rates vary from about £4 to £2 per H.P. Millowner is further entitled to benefit and use of water for such other purposes as shall not sensibly diminish quantity or affect regular and uniform passage of water to mills below, or deteriorate quality thereof so as to render it unfit for washing, bleaching, and ordinary culinary purposes.—*Geo. C. Bunker.*

Fluctuations of Annual Rainfall: Three Driest Consecutive Years. JOHN GLASSPOOLE. Water & Water Eng., **26:** 469, December 20, 1924. Trans. Inst. of Water Engineers, **29:** 83, 1924. Consideration of subject as it affects British Isles. In discussing rainfall of years 1868 to 1921, average utilized is that for period 1881 to 1915, which is closer approximation to true normal than that for whole period. The driest triennium over British Isles generally was 1887 to 1889, fall in these years being 89 per cent of average, compared with 94 per cent for the next driest triennium. Eighty per cent, or less, has occurred in period under discussion over only small fraction of the total area of British Isles, but geographical distribution is not such as to suggest its future confinement solely to those areas. There is evidence from map of mean deviation for anticipating occurrence of deficiencies of this amount in central regions of England and of Scotland. The rainfall of three consecutive years is twice as variable in central districts of England as in north-west of Ireland. Values appreciably less than 80 per cent in the 54 years are rare. Values appreciably greater than 80 per cent occur in coastal regions, and especially in north-west of Ireland. Retention of use of 80 per cent in water supply calculations seems justified, except in north-west of Ireland, where evidence of small fluctuations is so pronounced that allowance of 80 per cent could be increased. Illus.—*Geo. C. Bunker.*

The Biology of Jersey Waterworks. WILFRED RUSHTON, P. A. AUBIN, and A. J. JENKINS. Water & Water Eng., **26:** 487, December 20, 1924. Trans. Inst. of Water Engineers, **29:** 111, 1924. Jersey, largest and most southerly of Channel Islands, is situated in Bay of St. Malo, about 15 miles from coast of Normandy. Water supply is derived from watershed of St. Lawrence stream, an area of 1200 acres. Much water is derived from springs issuing from volcanic rocks, but bulk of flow is drainage from cultivated land. Average rainfall over period of 35 years was 33.68 inches and minimum was 16.67 inches in 1921. Final collecting stream enters small settling pond, whence water flows through Dannemarche reservoir (capacity, 33 million gals.), and thence through pipe line (about 1 mile long) into Millbrook reservoir

(capacity 11 million gals.). Approximately 500,000 gallons per day are filtered through open sand filters with area of 2180 square yards. Rate exceeding 3½ inches per hour is seldom necessary and bacteria are almost entirely removed. Prior to use of Dannemarche reservoir, water did not remain long in storage and algae did not cause much trouble, but by putting it into service storage capacity was increased 3½ times with result that water remained longer in stagnant condition and at higher temperatures; especially in lower, or Millbrook, reservoir. Weekly samples were taken throughout year at following points: inlet and outlet of settling pond; inlet at Millbrook reservoir; and inlet to filters. Investigation was undertaken to ascertain: (1) what organisms were likely to cause trouble; (2) if any such were found, when, where and how to deal with them in most satisfactory manner from point of view of management; (3) to investigate certain obscure relations between algal and fish life; (4) the most advantageous method of rearing trout under local conditions. Starting at end of April, 1923, rapid increase in Coelastrum occurred and at end of June 4576 per cc. were present in water going upon filters. Water was clear, but of deep bottle-green color. Rate of filtration was slowed very considerably, and in view of increasing consumption of water matters looked serious. Copper sulphate was applied to reservoirs as follows: Quantity equal to 0.05 parts per million gallons was dissolved in sufficient water to make a solution of 1 pound to 5 gallons; using ordinary agricultural spraying machine from a boat, whole surface of Millbrook reservoir was sprayed, and dose repeated on 3 separate days, thus making a total dose of 0.15 parts per million gallons. Dannemarche reservoir was then sprayed on 4 consecutive days, each spraying being equivalent to 0.05 parts per million. Seven days after last treatment Millbrook reservoir was again sprayed as before on 3 consecutive days making total of 0.3 parts for this reservoir. Seven days after final spraying of this reservoir green algae had decreased to 356 per cc., and at end of another 7 days to 68, from 4992 on day prior to first spraying. Similar reduction followed in other reservoir whence it would appear that 0.15 parts per million gallons was sufficient dose. For some days after treatment fermentations were slightly affected in local breweries. As yeast is extremely sensitive to the action of copper sulphate, it is essential, where breweries are supplied, to use minimum quantity. Chemical analysis failed to detect trace of copper sulphate in filtered water. Neither were adult trout, trout fry, nor the crustacea, Daphnia, staple food of the young trout, affected by treatments. Spraying of copper sulphate has following advantages over towing it in bags: (1) Salt is evenly distributed over surface instead of in streaks, in which for a time strength is sufficient to be injurious to fish life; (2) Diffusion is entirely vertical, whereas with bag method diffusion between two passages of bag is, so far as surface layers are concerned, horizontal; a slow, uncertain, process in still waters; (3) By dividing dose there is greater certainty of whole surface being treated and, moreover, if microscopic examination is carried out concurrently, treatment can be stopped as soon as desired effect is obtained. Illus.—*Geo. C. Bunker.*

Troubles, Causes and Remedies, with a Swimming Pool Using a Recirculation System. Robt. O. Friend. Jour. Amer. Assoc. for Promoting Hygiene

and Public Baths, **7**: 71–74, 1925. A practical paper.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The Development of Bathing in Holland. Mme. A. M. RUYSCH DAWES-DEKKER. Jour. Amer. Assoc. for Promoting Hygiene and Public Baths, **7**: 66–70, 1925.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Bath, Britain's Healing Shrine Throughout the Ages. JOHN HATTON. Jour. Amer. Assoc. for Promoting Hyg. and Public Baths, **7**: 57, 1925. Historical and descriptive, with plan and photograph of old Roman baths.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Safeguarding the Nation's Health with Outdoor Swimming Pools. WALTER S. HOOD. Jour. Amer. Assoc. for Promoting Hygiene and Public Baths, **7**: 50–53, 1925. Four hundred new outdoor pools will be completed this year according to the Portland Cement Association. Advantages and means of financing construction of pools.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Saratoga's Mineral Baths. A. S. DOWNS. Jour. Amer. Assoc. for Promoting Hygiene and Public Baths, **7**: 42–44, 1925.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

American Springs and Health Resorts. JOSEPH E. GICHNER. Jour. Amer. Assoc. for Promoting Hygiene and Public Baths, **7**: 45–46, 1925.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The Cure at Saratoga Springs by Mineral Waters and Baths. JOHN F. HUMPHREY. Jour. Amer. Assoc. for Promoting Hygiene and Public Baths, **7**: 35, 1925.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The Mineral Springs of Saratoga and Their Future Development by the State of New York. GEORGE FOSTER PEABODY. Jour. Amer. Assoc. for Promoting Hygiene and Public Baths, **7**: 31–35, 1925.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Some Observations on Goiter. FRANCIS E. FRONCZAK. Jour. Amer. Assoc. for Promoting Hygiene and Public Baths, **7**: 24–31, 1925. Rochester, N. Y., preventive practice. School inspection and notification of parents of affected children. Between Sept. 11 and Oct. 2, 1923, tried for first time adding iodine to city water. Dose applied 16.6 pounds per day, or 365 pounds NaI. At tap the amount was 4 or 5 to 50 parts per billion. Dosage about 40 per cent effective. Normal content about 1 to 4 or 5 parts per billion. —*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The Natatorium at the Zuider Park at the Hague. Anon. Bulletin trimestriel Assoc. International de Bains populaires et de Propreté, **12**: 3, 11–15, 1925. Large open air natatorium opened in May, 1925. Has no equal in Europe. Pool is divided into two parts; for men and women respectively.

Each part is 50 m. x 25 m. and has a shallower part 30 m. x 25 m. Maximum depth 3.3 m. Contents of the two basins 8000 cu.m. Separating wall between the two basins may be removed to facilitate contests. Water used is iron-bearing. Filters and re-circulation system are provided.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*)

The New Municipal Bath House at Vienna Called the Amalienbad. JOHANN BAROUSCH. Bulletin trimestriel Assoc. internat. de Bains Populaires et de Propreté, **12:** 3, 1, 1925. Capacity 1250 bathers at one time. All types baths provided. Pool 12½ x 33⅓ m. Maximum depth 4.8 m. To be opened in spring of 1926.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The New Water Supply of La Rochelle, France. ALFRED SALMON. L'Eau, **18:** 63–68, June 15, 1925 and 75–78, July 15, 1925. Wells and collecting galleries at Fraise and at Anais, with pumping equipment, and concrete reservoirs. Plans and photographs. *Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The Water Supply of Besançon. PAUL LHEUREUX. L'Eau, **18:** 26–30; 50–54, 1925. In 170 A.D. Romans build aqueduct from Arcier springs. Other supplies have since been developed from similar sources. Greatest point of difficulty has been supply of newer and higher outskirts. Wells in the Doubs river gravel have lately been tried.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

New Intake from Lake Leman for Geneva, Switzerland. Anon. L'Eau, **18:** 55, 1925. Steel pipe 80 cm. (32 in.) diameter and 800 m. long takes water through strainer at depth of 32 m. Thickness of steel plate 5 mm. Flexibility assured by special castings permitting movement of 25° at each joint. Pipe was drawn out after assembly on shore.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Pumping Water from Lake Leman During the Dry Weather of 1920–1. G. KERNEN. L'Eau, **18:** 39–41, April 15, 1925. The towns of Lutry and Cully took water through small pipes hastily run out into lake. Lutry pipe was 100 m. long, 60 mm. (2½ in.) inside diameter. The strainer was down about 15 m. from surface and held 2 m. from bottom by six-sided wheel-like frame. Placing pipe took about two hours.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The Romans in Northern Africa. GASTON MARGUET. Semaphore Algerien, December 19, 1924; L'Eau, **18:** 10–11, 1925. Many barrages and shallow reservoirs were constructed by the Romans in southern Tunis and Algeria. They were for storage of water in spring and summer and varied from a few sq. m. to several hectares in area. Depth was seldom more than 2 or 3 m. Tunis and vicinity received its water from springs of Zaghouan and Djouggar through aqueduct of Carthage, built by Adrian, and rebuilt

by Sidi Sadok Bey in 1859. Other aqueduct supplied El-Djem and Azzefoum.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The Water Supply of Montpellier, France. Anon. L'Eau, **17**: 123–4, 1924. Original supply completed in 1766 was from St. Clement spring and was designed by Pitot. Present supply taken from Lez spring in 1854. This water is impure at times and contains so much $Ca(HCO_3)_2$ as to cause precipitation on escape of CO_2. It is planned to chlorinate and possibly to filter and soften.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Purification of Drinking Water. E. ROLLANTS Rev. hyg., **47**: 534, 1925. Review of English and American articles of 1923–4.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Apparatus for the Automatic Control of the Sterilization of Water by an Antiseptic. IGONET and DE LAROCHE. Rev. hyg., **47**: 380–2, April, 1925. Device using two Wolff bottles, one to contain hypochlorite, controlled by displacement by flow of water through Pitot tube into second bottle.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Standardization of Methods for the Bacteriological Analysis of Water. P. VIGNE and R. CREMIER. Rev. hyg., **46**: 1168–1180, December, 1925. Results of questionnaire sent to water analysts in France showed no general agreement in practices. Standardization of procedures is needed in order that there may be common basis of interpretation.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The Sterilization of Water of Shellfish Beds. H. VIOLLE. Rev. hyg., **47**: 33–35, 1925. Shellfish are not injured by dose of 2 to 3 p.p.m. Cl which is sufficient to sterilize sea water in 2 hours. Chlorine, after combining to form chlorides, is inappreciable when water already contains 30 to 40 g. NaCl per liter. If it takes 1 hour to kill bacteria in surrounding water, it takes 24 hours to sterilize the intervalvular water and 3 or 4 days to kill any bacteria in the pulp of the shellfish.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Endemic Goiter and Potable Waters. F. M. MESSERLI. L'Eau, **18**: 14–16, February 15, 1925. Messerli's investigations have convinced him of the water-borne character of goiter. Due to use of polluted surface water, it ought to be combated by hygienic measures such as water purification. Advises continuance of iodine prophylaxis.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

The Actual State of the Endemic Goiter Problem. E. COULAUD. Rev. hyg. **47**: 5–28, January, 1925. Historical summary. Suggests that iodine deficiency is not cause of simple goiter, but that iodine is more like natural corrective, since it is claimed that goiter is reduced but not entirely suppressed by iodine treatment. Iodine treatment is not without its dangers. Likeness of goiter to bacteria-borne diseases and influence of heat on destruc-

tion of goiter-producing properties of a water are emphasized. Numerous references.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Goiter Survey of Saginaw, Michigan. WM. DE KLEINE. Public Health (Michigan), **13** (n. s.): 146–9, May, 1925. Saginaw has municipal water supply which is not safe for drinking purposes and has about 175 driven wells for obtaining drinking water. There are many private wells both shallow and deep. Survey of school children in 1924 showed that goiter was more prevalent among those using shallow wells. Chlorine in wells varied from 9 to 3350 p.p.m., and iodine from 6 to 342 parts per billion (equivalent to 0.024 to 1.3 mgm. per gallon). High chlorine does not necessarily indicate high iodine, but the two usually go together.—*Jack J. Hinman, Jr.* (*Courtesy Chem. Abst.*).

Treatment of Boiler Feed Water by a Zeolite Softening System. S. T. POWELL and J. H. WOLFE. Ind. & Eng. Chem., **17**: 6, 584, 1925. Since installation of zeolite water softener considerable economy has resulted in boiler operation at water-gas plant of Consolidated Gas, Electric Light, and Power Co. at Baltimore, Md. Practically all steam generated is used to produce water-gas, thereby necessitating 100 per cent make-up boiler feet-water. Prior to zeolite softening, frequent internal boiler cleaning was required; but since its inauguration in 1922, no cleanings have been necessary and no signs of caustic embrittlement have appeared. No serious foaming has been observed although there has been observed at times an increased tendency toward mild foaming. 81,470,000 gallons per year have been softened at an average cost of 4 cents per 1000 gallons, including labor, depreciation, salt, etc.—*Linn H. Enslow.*

Phenols, Determination of, in Natural and Polluted Waters. LOREN R. VANCE. Ind. & Eng. Chem., **17**: 7, 751, July, 1925. One or more liters of sample, after precipitation with caustic soda, filtration, and oxidation by hydrogen peroxide, are evaporated to 200 cc. Excess caustic alkalinity is maintained during evaporation. It is later made acid by addition of citric acid. Subsequent distillation produces an aqueous solution containing all of phenol. To an aliquot of this is added the prescribed quantity of Folin-Denis phenol reagent and one hour allowed for color development. Color is matched against colors produced from freshly prepared aqueous phenol solutions to which same reagent is added in ratio of 1 cc. for each 1 p.p.m. phenol present using 50 cc. portions for the comparisons. Sample and standards should not contain more than 4 p.p.m. phenol for accurate readings.—*Linn H. Enslow.*

Tension as a Factor in Priming of Steam Boilers. E. B. MILLARD and T. E. MATTSON. Ind. & Eng. Chem., **17**: 7, 685, July, 1925. Experimental work in laboratory, followed by tests in small boiler, failed to furnish evidence of any connection between priming or foaming in boilers and surface tension of boiler water.—*Linn H. Enslow.*

The Water Supply of Price City, Utah. J. W. PLANT. Engr. & Contr., **63**: 781–3, 1925. Supply is obtained from Colton Springs, about 25 miles from Price. Pipe line varies from 8 to 15 inches according to grade. Vitrified tile pipe was used for 9 miles through a canyon and wood stave fir pipe for 16 miles. Installation of meters during 1921 and 1922 eliminated waste and doubled water receipts.—*C. C. Ruchhoft.*

Sanitation in San Salvador. ANON. Engr. & Contr., **63**: 1033–40, 1925. Construction of sewers, waterworks, and street paving for this Latin American city of 125,000 persons is described.—*C. C. Ruchhoft.*

Protecting the Underground Water Supply of Kearney, Nebraska. HARRY H. MOLE. Engr. & Contr., **63**, 762–64, 1925. Supply is obtained from 4 wells 400 feet apart at right angles to underground flow. All privies and cesspools lying within radius of 1000 feet from each well were condemned and sanitary sewers constructed for this area.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Water Softening at St. Paul. ANON. Engr. & Contr., **63**: 764, 1925. Lime soda process of water softening was tried at new St. Paul purification plant and hardness, expressed as $CaCO_3$, reduced from 185 to 75–90 p.p.m. This was considered most satisfactory for all round city use.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

The Laying of Cast Iron Pipes. H. H. BAUGHMAN. Engr. & Contr., **63**: 743–4, 1925. A description of ordinary methods is given.—*C. C. Ruchhoft.*

Some Notes on Electrolysis of Water Pipes. WALDO S. COULTER. Engr. & Contr., **63**: 747–50, 1925. Electrolysis caused by stray currents from electric railway systems is discussed. Insulated pipe joints, or insulated negative return conductors, are suggested as best methods for prevention.—*C. C. Ruchhoft.*

Metering the Water Supply of the City of Chicago. HENRY A. ALLEN. Engr. & Contr., **63**: 751–60, 1925. Universal metering plan, which will cost $18,000,000 in next ten years, is proposed. It is shown that if present plan is continued for thirty years, it will cost Chicago $380,000,000 more than universal metering plan.—*C. C. Ruchhoft.*

Water Purification in Ohio. H. W. STREETER. Eng. & Contr., **63**: 541–2, 1925. Results of year's survey of purification efficiencies of ten municipal water filtration plants on Ohio River are given.—*C. C. Ruchhoft (Courtesy Chem. Abst.).*

Habits and Vitality of Certain Bacteria. H. W. CLARK. Eng. & Contr., **63**: 553–4, 1925. Differentiation studies on Bact. coli group from water seem to show that presence of Bact. coli indicates recent pollution; of Bact. aëro-

genes, alone, no fecal pollution; and of Bact. cloacae, contamination which is very distant, or much attenuated.—*C. C. Ruchhoft* (*Courtesy Chem. Abst.*).

The Improved Venturi Flume. RALPH L. PARSHALL. Proc. Amer. Soc. Civ. Eng. **51:** 7, 1340–49, September, 1925. Measurement of flowing water in irrigation practice often requires that little loss of head be sacrificed. Flume has converging inlet, parallel-sided throat, and diverging outlet. All side walls are vertical. Inlet has a level floor, each side converging at rate of 1 foot in 5 feet of length. Floor of throat slopes downward with vertical fall of 9 inches in horizontal distance of 2 feet. Outlet floor slopes upward at rate of 6 inches in 3 feet, and each wall diverges at rate of 1 foot in 6 feet of length. Lengths of throat and outlet of flume are 2 and 3 feet, respectively, for all sized flumes from 1 foot to 8 feet. Approximate discharge in second-feet = 4 $WH_a^{1.522}$ $W^{0.026}$. W is width of flume, or crest length, in feet; and H_a is upper head, in feet. Increased velocity of water in throat section causes hydraulic jump below in diverging outlet, and about 70 per cent of lost head is regained. One advantage of this type of measuring device is that it will operate in sand- or silt-laden streams without trouble. Chief advantage, however, is that it operates successfully with small loss of head. —*John R. Baylis.*

Multiple-Arch Dam at Gem Lake on Rush Creek, California. FRED O. DOLSON and WALTER L. HUBER. Proc. Amer. Soc. Civ. Eng., **51:** 7, 1310–32, September, 1925. Gem Dam was built in 1915 and 1916, and is of multiple-arch type—having 16 complete arches of 40 feet each. After 8 years, concrete had partly disintegrated by freezing. It was repaired by pouring concrete gravity section back of each of arches, extending up to within 30 feet of their tops. Upper 30 feet of arches and buttresses appeared to be in perfect condition. Authors conclude that to prevent deterioration of concrete subjected to water pressure and extreme low temperatures, it is necessary that impervious concrete be obtained. Slightest penetration of water will be followed by deterioration, further penetration, and further deterioration.—*John R. Baylis.*

Permissible Canal Velocities. SAMUEL FORTIER and FRED C. SCOBEY. Proc. Amer. Soc. Civ. Eng., **51:** 7, 1397–1413, September, 1925. Laws of hydraulics governing movement of loose silt and detritus in open channels are only distantly related to laws governing scouring of a canal bed and are not directly applicable. Colloids in either material of canal bed, or in water conveyed by it, tend to cement particles of clay, silt, and sand in such a way as to resist erosive effects. Irrigation canals may be designed for velocity that is permissible when seasoned by age, as demand for water usually grows with age of canal. More conservative velocities should be chosen for canals likely to be placed under peak load shortly after construction.—*John R. Baylis.*

Side Channel Spillways: Hydraulic Theory, Economic Factors, and Experimental Determination of Losses. JULIAN HINDS. Proc. Amer. Soc. Civ.

Eng., **51**: 7, 1350–96, September, 1915. Flow may be computed by Bernoulli's theorem, using experimentally determined coefficient of loss, similar to that of friction in ordinary flow; but such coefficient would not be constant and would need to be determined separately for many different sets of conditions. This may be avoided by utilizing law of conservation of linear momentum for determining flow. Formulas for this purpose are developed. Systematic method of determining most economic design is suggested.—*John R. Baylis.*

58th Annual Report of the Commissioner of Water Works in the City of Erie, Pa., for the Year Ending December 31, 1924. 68 pp. Daily average consumption was 22,216,418 gallons, and per capita consumption 188 gallons (108 after deducting metered trade consumption). Cost of collecting, purifying, and pumping, including depreciation, was $21.927 per m.g. Addition of $230,674.46 to surplus was effected during year, notwithstanding gratuitous water supplied to City and Bd. of Education to value of $51,039.61. Number of gallons pumped per pound of coal used was 255.6. Report of filter plant includes monthly average figures for bacteriological, chemical and physical quality of raw and filtered water and data on quantities of chemicals applied. Yearly average amount of alum applied was 0.196 grains per gallon, and of hypochlorite, 0.36 p.p.m. No positive results were obtained in 616 1 cc. samples of filtered water examined for B. coli. Average cost of service laid was $21.80 and average length, 18 feet, 5 inches. Extensions to plant included four additional filter beds of 2 m.g.d. capacity each, at cost of $113,976. —*R. E. Thompson.*

A Method of Measuring the Water Temperatures of Lakes at Different Depths. Frank A. Stromsten. Science, **62**: 34–6, July 10, 1925. Electrical indicating thermometer of platinum wire resistance type described, advantages of which are reliability, simplicity of operation, and rapidity in making readings. Needle of indicator usually requires 1–2 minutes to come to rest—. *R. E. Thompson.*

Corrosion of Iron. J. N. Friend. Iron and Steel Inst. Carnegie Scholarship Mem., **11**: 156 pp., 1922. From Chem. Abst., **17**: 958, March 20, 1923. Critical survey of present knowledge of corrosion of cast iron and steel. As general rule, cast iron containing flakes of graphite is more susceptible to acid attack than close-grained white iron. Ferrite is much more readily attacked than carbide. Alkalies have but slight effect upon cast iron. Corrosive action of water alone increases enormously with temperature. Artificially softened water is much more corrosive than untreated water. Introduction of alloying elements may effect corrodibility indirectly (e.g., silicon tends to throw out graphite, rendering metal porous and hence more susceptible) or directly (sulphur exists as sulphides, which markedly accelerate corrosion). Effect of carbon is directly dependent upon its condition. Graphite formation increases corrosion, while with combined carbon corrosion is much less. Manganese tends slightly to reduce corrodibility. Phosphorus has almost no influence on rate of corrosion and silicon has no direct influence. Concerning relative corrodibility of steel, wrought iron and cast iron, no simple

answer can be given. With neutral corroding mediums at rest, with few exceptions cast iron had lowest rate of corrosion, with steel second and wrought iron most susceptible to attack. With neutral corroding mediums in motion, in general cast iron had greatest rate of corrosion, with steel and wrought iron about equally corroded. Cast iron in general is very inferior to steel as regards resistance to all concentrations of acids. Contact between steel and cast iron increases markedly rate of corrosion over all ranges of temperature. Metals such as zinc and those more readily oxidized than iron, protect latter. In paints to protect iron against subaqueous corrosion, with increasing amount of oil and constant weight of pigment there is decided decrease in efficiency. With same weight of oil and increasing weight of pigment, protection afforded increases to point of maximum efficiency and further increase causes distinct reduction in protection. Maximum protection is effected by paint 50 per cent oil and 50 per cent pigment. Chief functions of pigment are to afford mechanical support to linoxyn and to reduce permeability. By increasing relative amount of pigment greater protection should be afforded, but there is a limit to amount of pigment that given weight of oil can efficiently bind, which when exceeded, protective power is reduced. Linseed oil is polymerized when heated in absence of air, yielding thicker litho oil which upon settling possesses minimum porosity and maximum resistance to chemical disintegration. As long as mill scale, which adheres very tenaciously, remains intact, very efficent protection is afforded, but if oxide becomes cracked, corrosion proceeds with great rapidity. Cheapest and most effective method of protection is to paint metal with scale still on, after first removing only loosely adhering flakes and rust. Influence of strain upon corrosion may be explained by studying distribution of energy absorbed in rupturing iron. As much as one half work done in stretching steel up to limit of rupture may be stored up permanently. This energy is liberated when metal is oxidized, the metal being attacked more readily, its potential rising with increased strain. This reasoning correlates with all theories of corrosion (cf. C. A. 15, 3012), and also with data obtained on stainless and high-nickel steels, which, while almost incorrodible in normal condition, are relatively very much more corroded after having been strained. Corrosion reaches maximum at temperature of approximately 80°. Plotting loss in weight against temperature accurately shows relative corrodibility at various temperatures. —*R. E. Thompson.*

New Calculations for the Determination of the Strength of Flanges. Oswald-Klinck. Chem. App., **10:** 3–4, 1923. From Chem. Abst., **17:** 1169, April 10, 1923. Mathematical formulas.—*R. E. Thompson.*

Zeolites and Their Commercial Applications. Lucien Maugé. Industrial chimique, **10:** 14–8, 1923. From Chem. Abst., **17:** 1291, April 10, 1923. Description of zeolites, their manufacture and uses, particularly for water purification.—*R. E. Thompson.*

The Preparation and Comparative Performance of Base-Exchange Water Softening Materials. E. B. Higgins and J. P. O'Callaghan. Chem. and Ind., **44:** 882, September 4, 1925. Discusses early history of zeolites and

production of Permutit by Water Softeners, Ltd. States that synthetic zeolite made by weight, or precipitation, method was prepared by Water Softeners, Ltd. and marketed as Permutit 31. Formula and method of manufacture are given. Method of manufacture of Permutit Type B, made from glauconite, is given. It is stated that material made from glauconite is much more resistant to mechanical wear and effect of carbonic acid than is material made by precipitation process.—*A. M. Buswell.*

Recent Experience with Doucil as a Water-Softening Material. T. P. HILDITCH and H. J. WHEATON. Chem. and Ind., **44:** 885, September 4, 1925. Points out that Doucil is not a zeolite since it has formula Na_2O, Al_2O_3, $5SiO_2$. Material therefore differs from Permutit B. No deterioration due to effect of carbonates has been observed on this material.—*A. M. Buswell.*

An Act Concerning an Investigation and Report on the Potable Water Resources of the State. Conn. Health Bull., **39:** 7, 136, July, 1925. State Geological and Natural History Survey of Connecticut is directed to report to the next session of general assembly upon water resources of the state.—*E. S. Chase.*

Physical Connections Between Public Water Supplies and Polluted Supplies. Anon. Bull. Indiana State Bd. Health, **28:** 7, 108. Indiana State Board of Health has ordered "that any and all physical connections between any public water supply, whether municipally or privately owned, and any industrial, commercial, or other water supply obtained from surface source, shall be discontinued on or before June 1, 1924, and that no such physical connection shall be made or established subsequent to the promulgation of this order."—*E. S. Chase.*

Ancient Water Systems. Anon. Michigan Public Health, **13:** 5, 153. Brief interesting account of early water supplies.—*E. S. Chase.*

Municipal Water Softening. W. C. HIRN and E. F. ELDRIDGE. Michigan Public Health, **13:** 6, 163, June, 1925. Part of preliminary report of industrial water survey conducted in Michigan by Bureau of Laboratories of Michigan Dept. of Health. Reprint may be secured, upon request, of the Dept. at Lansing. Article deals briefly with development of water softening, use of softened water by railroads, studies on after precipitation, and chemistry of hard water and water softening. Interesting data are given to show economic loss due to use of hard water, such as excessive soap consumption, coal wasted in boilers, and installation of duplicate soft water supplies in the individual house. The subject of municipal water softening and costs thereof are also given. Distribution of hard waters in Michigan is shown by map.—*E. S. Chase.*

Report of the Bureau of Engineering, Pennsylvania Dept. of Health. W. L. STEVENSON. The Listening Post, **3:** 24–26, 15. Review of activities of Bureau for two year period ending May 31, 1924. Some 172 water filter plants, serving

4.5 million people, and 330 chlorination plants, serving 1.7 million people, in service in Pennsylvania. In 1921 typhoid outbreak was caused by infected water supply. In 1923, suit for damages by widow of one victim resulted in award of $2000. This case established a precedent in Pennsylvania.—*E. S. Chase.*

The Oradell Dam of the Hackensack Water Company. NICHOLAS S. HILL, Jr. Proc. Amer. Soc. Civ. Eng., **51:** 8, 1569–90, October, 1925. Unique dam of considerable size was constructed by Hackensack Water Company in 1922. Unusual design was attempt to meet special conditions found at particular site. Spillway section is essentially an earth dam 50 to 90 feet thick at base. Up-stream face of embankment was formed by existing earth and timber crib dam with its wooden sheet-pile cut-off extending about 20 feet into the earth. Down-stream face and toe are encased in reinforced concrete envelope, supported on round piles. Continuous line of interlocking steel sheet-piling at up-stream edge of floor of concrete envelope extends to hardpan. With concrete cut-off wall of sluice-gate section, they form together continuous cut-off entirely across new dam. Earth fill forms a stable and impervious dam in itself, but is not proof against burrowing animals, nor against scouring if it should be overtopped. Reinforced concrete envelope performs function of masonry core-wall and protects top and down-stream face against scouring. Below toe of concrete envelope, stream channel is paved for distance of 45 feet.—*John R. Baylis.*

SOCIETY AFFAIRS

CALIFORNIA SECTION

The sixth annual convention was called to order at Santa Cruz by George W. Pracy, Chairman of the California Section, who presided at all of the sessions and was able to bring out much discussion of all papers, particularly the symposiums.

Morning and afternoon sessions were held in the Casino, Hotel Casa Del Rey, which also adequately housed the twenty-nine exhibits which were very attractively arranged. Evening dinner meetings were held in the main dining room of the Casa Del Rey.

The following program was presented.

Thursday, October 15

10:00 a.m.

Sun Room, The Casino, Hotel Casa Del Rey
General Get-Together, Registration and Review of Exhibits

Thursday, 2:00 p.m.

Sun Room, The Casino, Hotel Casa Del Rey

Convention called to order by George W. Pracy, President California Section, American Water Works Association.

Address of Welcome. Hon. W. O. Kerrick, Mayor of Santa Cruz.

Reading of papers

Recent Improvements in the Santa Cruz Water System. Arnold Williams, City Engineer, Santa Cruz.

Symposium: Service Installation Methods and Standards. Discussion opened by George Read, Superintendent, Meter and Service Department, Bureau of Water Works and Supply, Los Angeles, California. Read by A. P. Lovell, Supt. Water, San Diego.

Symposium: Meter Maintenance Methods. Discussion opened by J. H. Fagg, Pacific Gas & Electric Corporation, Stockton, California. Read by G. E. Sedgwick, Dist. Mgr., Pacific Gas & Electric Co., Dixon, California.

Thursday, 6:30 p.m.

Informal Dinner

Hotel Casa Del Rey

The Secretary reported the admission during the year of 22 active, 2 corporate and 4 associate members, making 28 in all. There were 2 resignations, B. J. Robinson and J. C. McCoughern, making a net growth of 26, bringing our present membership to 1 honorary, 103 active and corporate, 11 associate—total membership, 125; the result of this growth being the award of the Nicholas S. Hill cup.

The Treasurer reported expenses of stationery, printing and postage for the 1925 Convention amounting to $80.10, leaving a balance of funds in the bank of $106.90.

The Nominating Committee, composed of past Chairmen G. A. Elliott, Chairman, L. M. Anderson, Fred J. Klaus, brought in the following nominations.

C. B. Jackson, Chairman; S. B. Morris, Vice-Chairman; P. Diederich, Member of Executive Committee; John Burt, Member of Executive Committee; Paul E. Magestadt, Secretary-Treasurer.

On motion by Mr. Ryland, seconded by Mr. Prugh, the above nominees were unanimously elected.

A. P. Lovell, Superintendent Water Department, San Diego extended an invitation to the Association to hold their next Convention in the City of San Diego, which was accepted on motion by Mr. Anderson.

Fred M. Randlett, Member of the Governing Board of the American Water Works Association, gave an interesting talk of the work of the Association, particularly describing the water works manual and offering his regrets at not being able to present the Nicholas S. Hill cup to the Section during the Convention, owing to its non-arrival.

Leslie Cranborne, Secretary, Chamber of Commerce of Santa Cruz, gave a very interesting address upon State Unity and Conservative Development. He also spoke entertainingly of the win-

ning of the title of Miss America, the Santa Cruz Entry at Atlantic City.

The "Orpheus Four," of which H. M. Dudley, of the McWane Cast Iron Pipe Company, is a member, gave a number of excellent selections through the courtesy of his Company.

There were present 142 members and guests.

Friday, October 16

10:00 a.m.

Sun Room, The Casino, Hotel Casa Del Rey

Reading of Papers

Design and Construction of Concrete-Lined Distribution Reservoirs. I. E. Flaa, Chief Draftsman, Spring Valley Water Company, San Francisco, California.

Design of Balancing Reservoirs and Stand-Pipes for Flat Cities and Communities. E. K. Barnum, Engineer, Fresno City Water Corporation.

Seismic Activity in Santa Barbara, by V. E. Trace, Supt. Water, Santa Barbara. Read by S. B. Morris, Superintendent and Chief Engineer, Pasadena Water Department.

Symposium: Jointing Methods for Water Mains. Participated in by J. I. Prugh and 15 other members present.

Friday, 2:00 p.m.

Sun Room, The Casino, Hotel Casa Del Rey

Reading of Papers

Relation of Railroad Commission to the Water Works Man. M. R. MacKall, Hydraulic Engineer, California State Railroad Commission.

Coöperation between the Water Works and Fire Departments in Decreasing Fire Losses. Thomas Baird, Chief Engineer, Fire Department, Fresno, Calif.

Adjustments. Frank P. Clark, Chief Adjuster, Spring Valley Water Company, San Francisco, California.

Methods Used in Moving 36-inch Riveted Steel Water Main. Judy I. Prugh, Superintendent Distribution, Sacramento Water Department.

Relation of Water Pressures, Service Sizes and Interior Fixtures to Complaints of Inadequate Water Service. V. E. Perry, Assistant Manager of Water Sales, Spring Valley Water Company, San Francisco, California.

Methods of Protecting Services and Meters during Street Grading and Paving Operations. P. Diederich, Supt. Public Service, Glendale, Calif.

Use of Mechanical Equipment in Trenching, Backfilling and Pipe Laying, by Thomas Brooks, Assistant Superintendent, Bureau of Water Works and Supply, Los Angeles, California. Read by Wm. F. Goble, Superintendent San Gabriel Valley Water Company.

The Secretary was instructed to address letters of appreciation to Mr. Pratchner and the Local Committee; Mr. W. O. Kerrick, Mayor, and to the City of Santa Cruz; Mr. Leslie Cranborne, Secretary, and to the Chamber of Commerce of Santa Cruz; Mr. R. W. Martindale and the Exhibitors Committee, and to Mr. Fred K. McDonald, Manager of the Hotel Casa Del Rey. The retiring officers were thanked by resolution passed by the meeting.

Friday, 6:30 p.m.

Hotel Casa Del Rey

Dinner Dance—Informal

As Guests of the Exhibitors

Members and guests were entertained with several dances and soprano solos and by the "Orpheus Four" through the courtesy of the Exhibitors. Following the dinner, dancing was enjoyed until 1 a.m. There were 229 members and guests present.

Saturday, October 17

As guests of the City and Chamber of Commerce of Santa Cruz, the members and guests of the Convention went on an automobile trip through the City of Santa Cruz where the Water Department's new distribution reservoir was inspected, and thence along the Cliff Drive, stopping at the Country Club at Aptos for luncheon, 76 sitting down for lunch.

Following the luncheon, W. K. Dodworth of Monroe, Lyon and Miller, Inc. led the party through their 2500 acre development of

seaside and mountain homesites, after which the party returned to Santa Cruz where inspection was made of the City's pressure filter pumping plant. From here members drove to "Big Trees" in the Giant Redwood Forest near Santa Cruz, returning to Santa Cruz at 4 p.m.

Through the courtesy of the city and chamber of commerce of Santa Cruz, the ladies present at the Convention were entertained Thursday evening by a theater party and on Friday afternoon by a drive about the City and to the Giant Redwood Forest.

Throughout the Convention there was much discussion of every paper and all persons at the Convention, both members and guests, returned with a feeling of days well spent and are looking forward to the Seventh Annual Convention at San Diego.

There were registered during the Convention 105 water works men; 75 material men; 21 students and others and 46 ladies, making a total registration of 247.

CORRECTION

In the November, 1925, issue of the JOURNAL, p. 458, "Mr. Childs" should read "George G. Schaut." The stenographers credited Mr. Childs with the discussion on "Tastes and Odors."